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CATERPILLARS' DWELLINGS.—I.

By E. A. Butler.

AMONGST the caterpillars of butterflies and moths, the architectural instinct is developed chiefly in two directions. Some live in communities and construct a common dwelling-place; others, which are solitary in habits, either rear amongst the foliage of their food-plant some sort of tent or covering to serve as a snug and safe place of retreat and shelter, or else construct a portable receptacle into which the greater part of the defenceless body is thrust while the insect travels in search of food. In the formation of a common dwelling-place, no such wonderful ingenuity is displayed as characterizes the workmanship of bees, ants, or wasps, and for this several reasons may be assigned. In the first place, the architects are not perfect insects, but only immature creatures which live a very vegetative sort of life. Their communities, again, do not reach that high degree of organization which is implied in the term "social"; they form what were called by Kirby and Spence "imperfect societies," *i.e.*, the individuals of the tribe, though sharing in the construction of the abode which serves as a common means of defence, do not contribute to the common support, nor supply one another's needs in the way of food, but each looks after its own interests, and recks not what may befall the rest. And again, though they are larval forms, each is able to provide for itself from the moment of hatching; thus there are no helpless young to be tended, and this at one stroke removes the necessity for the multifarious duties that occupy so much of the time of truly social insects, and at the same time renders any elaborate structure unnecessary. Indeed, there is little more than their common descent from one batch of eggs, and the presence of the common food in their vicinity, to induce them to form any bond of association at all. Hence they are more appropriately styled gregarious than social. The common domicile, moreover, is not made by the heaping up of particles of foreign matter, nor by the excavation of galleries in earth or wood, so that no toilsome journeys in search of building materials, nor hard labour in the excavation of tenacious matter are requisite. The caterpillars' lives are much too fully occupied with eating to leave time or energy for such undertakings. The material made use of is simply silk spun from their own bodies, and the supply keeps pace with the increasing necessities of the case, till at last an extensive web is formed, whose dimensions are such that it lodges the whole community and still leaves plenty of room to spare.

There are not many British species that adopt this practice; those that do fall chiefly into three groups. One of these occurs amongst that interesting division, the rather large-sized and heavy-bodied moths called Bombyces, some of the densely hairy larvæ of which we have already discussed; the second, amongst a set of small moths called "knot-horns"; and the third is a genus called *Hyponomeuta*, which belongs to the division containing the smallest Lepidoptera in the world, and known as the Tineæ. To take these latter first. Most owners of gardens sooner or later come into collision with representatives of the genus *Hyponomeuta*. They are called "small ermine moths" (Fig. 1), and the different species are all very similar, having narrow, whitish or slate-coloured fore-wings with rows of black dots, and lead-coloured hind-wings with long fringes, and a clear transparent space at the base of the wing. The expanse of wings is generally under three-quarters of an inch; but when the moth is at rest, with its wings closed, it becomes a narrow cylindrical object, showing nothing more than the spotted, ermine-like fore-wings.

Fig. 1.—Small Ermine Moth (*Hyponomeuta padella*).

Hedges of hawthorn, apple trees, and euonymus shrubs are the particular kinds of vegetation most attacked by these elegant but destructive little pests. The young, fresh shoots of the shrubs are found spun together in early summer by a quantity of silken threads like a cobweb, and in the midst of the mass are to be seen a number of small black-spotted caterpillars, which are of a smoky or yellowish colour, according to the species. On being disturbed they wriggle violently, and either crowd together side by side in the centre of the web, or drop out of it, descending to the ground at the end of an improvised thread. Under the shelter of the web, they devour the surface of the foliage of the shrubs, thereby causing the remainder of the leaves to wither and shrivel up and turn brown. Apparently the caterpillars do not suffer from the assaults of birds, for the sticky and clinging threads would greatly incommode and annoy any bird that ventured to tamper with them; and as pretty good proof that they are amongst Nature's favourites may be cited their extreme abundance, which is often far greater on the Continent than even in this country, so that their ravages become sometimes a source of serious loss to the agriculturist. It is thus clear that they have found web-making an exceedingly paying transaction.

The early history of these little creatures is rather peculiar. The eggs are laid on the stems of the food-plant at the end

of summer, and are covered over by the mother with a layer of varnish. Towards autumn they hatch, but the young larvæ remain throughout the winter crowded together under the waterproof skin so thoughtfully provided for them. When the leaves appear in spring the little creatures, which throughout their life seem to have a wonderful faculty of looking after their own safety, come out from their shelter, and begin to burrow into the young leaves, devouring the soft matter underlying the cuticle, and thus exchanging the protection of their dome of animal varnish for shelter by a flat vegetable roof, which the leaf-skin now constitutes over their heads. When they have grown sufficiently, and their jaws have become strong enough to attack the leaf from the outside, they come out of their burrows and then begin to provide for their further safety by spinning a web, under which they continue to carry on the work of destruction. This will be their condition about midsummer. This is the period of their life when they are most annoying to the gardener, because when they have finished the leaves enclosed in one web they migrate to another spot and spin another, which they continue to inhabit till their rapacity has again brought about a dearth of food, when a further migration takes place. Thus, during the course of their life, several webs may be formed by the same batch, and the larger the colonies the more frequent will be the moves, so that the trees soon become covered with masses of sticky threads, which, quite apart from the actual damage done to the trees, are annoying as presenting an exceedingly untidy appearance. Sometimes there will be from one hundred to two hundred caterpillars in a single brood, and it is obvious that the daily provisions required for such an army will be considerable. The threads of the web, though apparently arranged quite indiscriminately, run pretty much in the same direction, and each caterpillar, forming its own line, seems to use that as a kind of climbing ladder, in preference to those of its neighbours. Hence results the parallelism of their position when they crowd together in the centre of the web. They run up and down their threads like sailors in the rigging of a ship, and can go almost as rapidly backwards as forwards.

When they are full fed each caterpillar spins a close-fitting cocoon of its own inside the general web, and within this it changes to a shining chestnut-coloured chrysalis. As all the members of one colony belong to the same batch, they all reach maturity about the same time, and form a cluster of cocoons in the midst of the web. This change is very rapidly made, the cocoon taking no more than a day to construct, so that the result is rather striking—one day we may see the wriggling caterpillars twisting about in the web, full of life and energy; the next, all is as still as death, and in place of the active grubs there is only a closely packed bundle of oval objects, reminding one of a cluster of "ants' eggs" done up in cobwebs. Thus even in their chrysalis condition they preserve their gregarious habits, while their customary faculty of self-preservation is again strongly asserted, for they are doubly protected, first by their own cocoons, and secondly by the web outside. But when they reach their perfect condition, an event which occurs in July, all these artificial aids to security are discarded, and the little moths sit about on the tree trunks and on blades of grass, as well as the leaves of their food-plant, in the most prominent positions without any attempt at concealment, their white satiny wings rendering them indeed doubly conspicuous against the darker background of their surroundings. They are, moreover, sluggish in the daytime, and if disturbed do not fly far. If they once gain a footing in a garden they are difficult to eradicate, and it is not easy to discover remedies that may be entirely relied upon. Of course, the surest remedy is to cut off the shoots on which the webs are found and burn them, but in bad attacks this involves a great waste of material as well as expenditure of time.

Turning now to the more or less hairy caterpillars of the Bombyces, we find one of the most noteworthy instances of web-forming amongst British species in the small egger moth (*Eriogaster lanestris*). This is in many respects a remarkable insect. It feeds on hawthorn, and occurs commonly on hedges in June and July, the chrysalis being formed in August. The moth appears, strangely enough, not in the summer time, as most of the related species do, but in February, sometimes in the next year to that of its larvahood, but frequently not till another twelvemonth has elapsed. In some cases a much longer time than this intervenes before its final change, as much as five years of pupahood having been recorded. This is a truly marvellous instance of suspended vitality, since of course no food is taken during all that period, and the moth is probably fully formed within the chrysalis at the end of its first winter. It is also remarkable that the insect should be able to pass through the heat of the summer without emerging, although that very heat is the necessary condition for the emergence of most Lepidoptera, and the factor instrumental in producing that emergence. It is only fair to note, however, that these long delays occur in confinement, when the external circumstances are not altogether natural, and of course it is impossible to say whether a similar course is followed by the insect in the wild condition with its natural surroundings.

The eggs are laid in spiral coils round the twigs of hawthorn while they are still bare of leaves (Fig. 2), and

Fig. 2.—Egg-Coil of Small Egger Moth, on hawthorn twig.

when laid they are wrapped round with dark grey wool, derived from the end of the mother's abdomen, whereby they are preserved from all the mischances that might otherwise befall them during the three or four months that must elapse before they are hatched. The ground colour of the caterpillars is black, and they are ornamented with a few bright yellowish spots and streaks; they remain very much of this appearance during all the first portion of their life. Then comes a sudden change. At the last moult they assume a reddish-orange coating, like velvet pile, on the upper surface of each segment, and become very handsome objects, so different from what they were before that they might easily be taken for a different species. Soon after hatching, the young caterpillars begin to surround themselves with a web, spinning the threads from twig to twig around their birthplace, on which the remains of the down-covered coil of egg-shells are still visible. As they grow, and gradually devour the foliage immediately around, the web is extended so as to enclose the twigs that are stripped, the caterpillars dispersing in the neighbourhood to feed at night, and returning to the nest by day. The web (Fig. 3) is very different from that of the small ermine moths, the threads being spun so close together and in such dense masses that nothing can be seen of its internal structure. When fully formed, it appears as a compact angular mass, often as much as eight or ten inches in diameter, and composed of white silk, usually more or less

discoloured by the traffic that goes on amongst it. Externally it appears to be one continuous mass of interwoven threads, but there are plenty of passages inside, into which the insects retreat on being alarmed. When undisturbed,

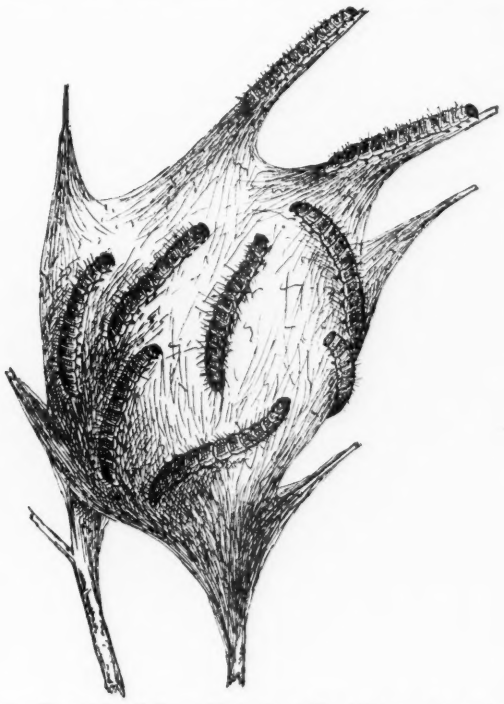

Fig. 3.—Nest of Small Egger Moth Caterpillar (*Eriogaster lanestris*). (About half natural size.)

they delight to rest on the outer surface, where they lie at full length, basking in the sun; and it is astonishing to see the rapidity with which, when danger threatens, even a large batch of them will move off and completely disappear into the depths of the nest, leaving no hint outside of their presence within. The nest is something like a whited sepulchre, for though it often looks clean enough outside, especially just after new outworks have been made, it is extremely untidy within, through the accumulation of cast skins, excrement, fragments of leaves, &c., which lie about entangled in dirty silk. Thus these web-forming caterpillars contrast in their habits most unfavourably with the scrupulous cleanliness of the truly social insects. In the size and opacity of the nest, as well as in its fixity of position, and in the greater freedom of the caterpillars, which not only lie habitually *outside* the nest and leave it to feed, but also, when full grown, abandon it altogether, the small egger moth differs entirely from the small ermines. A further difference appears in the act of pupation, for whereas the ermines form a cluster of cocoons inside the nest, the small egger caterpillars leave the nest and form their cocoons amongst the surrounding herbage, generally near the ground, and in doing so do not cluster together, but each follows its own taste in the selection of a locality in which to construct its strong, egg-shaped, pale brown case.

Several other insects, not distantly related to the small egger, construct and inhabit similar nests, especially while young. The best known of these is probably the lackey moth (*Clisiocampa neustria*), the flabby caterpillar of which, with its pale blue head marked with two black spots like eyes, and its body gaudily striped with red, blue, and orange, is often seen on apple trees and hawthorn hedges, to the former of which it has sometimes done irretrievable damage. The eggs of this moth are glued to the young twigs in the form of a tight-fitting bracelet, encircling the twig, but not covered with down. The gold-tail and brown-tail moths, again, whose stinging caterpillars we mentioned some time ago, construct elaborate nests with partitions and cells, to which in their youth they retire when not feeding, and in which also they hibernate. The processionary caterpillars of the Continent (*Cnethocampa*) form another excellent example of web-forming insects belonging to this group. The nest has but one opening, and this fact seems to be in some way connected with their habits of marching forth in long processions in the most regular order; for all must pass out at the same spot and in the same direction, and hence necessarily form a definite line of march—in one species, feeding on fir, going in single file, and in the other, feeding on oak, in a wedge-shaped body. Some tropical species, also belonging to the same group, vary the proceedings by forming, when they have come to the end of their larval life, a common nest in which to pass into the *chrysalis* condition. For example, the caterpillars of a moth found in Natal, and called *Anapha panda*, a cream-coloured insect with rusty red streaks on its wings, construct a large spherical chamber on a branch of their food-plant, some eight or ten inches in diameter, making its walls of several layers of rough brown silk of different degrees of consistency. This will accommodate from two hundred to three hundred caterpillars, each of which makes its own slight cocoon of light yellowish silk. These are placed side by side, all pointing towards one or other of the two places of exit, until the whole space is closely packed; thus the whole structure forms a kind of compound cocoon.

The "knot-horns" are a group of small moths not much larger than the small ermines, and amongst them are a number of insects belonging to the genus *Ephestia*, which feed upon dried fruits and other stored vegetable produce, and hence are commonly found in warehouses. They are gregarious and possessed of wonderful powers of multiplication, and these facts, coupled with their small size, often render their eradication an almost hopeless task, except by the sacrifice of the greater part of the stored goods. One species, *E. elutella*, is the pest of chocolate warehouses. The fragmentary and easily shifting nature of their food, the chocolate nibs, would cause them considerable inconvenience, and possibly even danger, as they climb about over the pile; therefore, to obviate this, they carry their silken threads with them wherever they go, and ultimately spin a large silken sheet entirely covering the stores, while the individual nibs are fastened together in all directions by silken threads; and thus in course of time the whole store is ruined, becoming an inextricable and loathsome mass of web, cocoa fragments, cast skins, and excrement. Another species, *E. Kühniella*, which has lately been introduced, and, notwithstanding great precautions, succeeded in establishing itself in London warehouses, more insidious still in its operations, and more disastrous in its results, similarly attacks flour, spinning its filthy webs over the sacks and amongst the grains of flour, till the whole is rendered utterly unfit for human food. Thus the damage wrought by these insignificant insects is by no means to be measured merely by the amount devoured; in their attempts to secure themselves amidst the treacherous piles of their easily disturbed food, they spoil with their penetrating webs and their disgusting remains far more than they actually consume.

(To be continued.)

WOODPECKERS.

By Harry F. Witherby.

THE woodpeckers (*Picidæ*) may be distinguished by the formation of the tail and head. The tail would, perhaps, strike the ordinary observer as the most curious part of the bird. It is composed of stiff but elastic feathers, and is used as a support for the body when climbing. The usefulness of the tail is seen to best advantage when the bird is pecking, for it then uses the tail as a prop to lean upon. This support enables the bird to throw its head right back, and then strike or hammer the tree with great force, and without losing its balance. The woodpecker's head, which is described later on, is even more remarkable than the tail.

Another peculiarity in the anatomy of the woodpecker is the small size of the keel of the breastbone. This dwarfing of the keel permits the bird to keep its body close to the tree while climbing.

Comparing the breastbone of a green woodpecker with that of a stockdove, a bird of about the same size, a remarkable difference is seen. The stockdove is endued with great powers of flight, and thus requires large pectoral muscles, and it possesses a deep keel to the breastbone; while the woodpecker, being endued with but moderate powers of flight, does not possess these large pectoral muscles, and as it is a climber it has the peculiarity of breastbone mentioned above.

The green woodpecker (*Picus viridis*), figured in our illustration, is the most common bird of the genus found in England. It may easily be known from other members of the family by its plumage, which is of a lovely olive green on the back, shading to a bright yellow on the tail coverts. The top of the head is of a rich crimson.

Green Woodpeckers; with entrance to nest in an old beech tree.

The male differs from the female in having a crimson "moustache," whilst the female has a black one. The peculiar marking, which has earned the name of moustache, is a line of feathers running from the base of the lower mandible under the eye to the end of the skull.

In common with all others of its genus, the green woodpecker is possessed of an immensely strong head and beak, admirably suited to the work of hammering trees in search of insects, and boring holes in them for nesting purposes.

When the bird is climbing a tree it grasps the bark with its feet, and, aided by the tail, proceeds by a series of jerks, always in an upward direction. Every now and then it will be seen to give the tree a tap with its beak, so as to ascertain by the sound given out where the tree is rotten. If the bird finds a decaying part in the tree, it continues its blows in order to disturb the insects under the bark, and as these try to escape they are secured with the tongue. Sometimes the bird will tear off a piece of bark while searching for food.

The tongue is very curiously formed; it is long and tapers to a hard sharp point like that of a needle, and is furnished at the tip with several hair-like barbs. By means of a very simple contrivance of the muscles of the head, the bird is enabled to project its tongue a great distance beyond the point of the beak. When the bird sees an insect in a crevice of the bark or in a hole into which it cannot put its beak, it thrusts its flexible tongue into the crevice and impales the insect, the barbs preventing it from escaping. Insects captured in this manner form the staple food of the green woodpecker. It occasionally feeds on ants and their eggs, obtained by scraping with its feet at their nests.

These birds have no song, but they utter a harsh mocking noise like a laugh, which may be heard from a good distance, and sounds very uncanny to the unaccustomed ear. The laugh is made, as a rule, in the bird's flight, which is heavy and undulating.

Very early in the year a decayed or decaying tree is chosen for the nest, and tree after tree is attacked until a suitable one is found. Small holes in trees, formed in this way, may always be found in localities frequented by woodpeckers. The bird, once satisfied with the tree of its selection (frequently an old beech), bores a hole some eighteen inches deep into it. The chips are carried away with the beak, while some of the wood-dust, similar to the saw-dust of carpenters, is left at the bottom of the hole. The eggs are laid and the young hatched upon the wood-dust, which takes the place of a nest. Both birds take their turn at sitting. The hole is usually made at about twenty feet from the ground, but I have seen one in an ash tree, containing eggs, not more than five feet from the ground. The hole is generally bored into the trunk, but it is occasionally found in one of the larger branches. The eggs are generally five or six in number, and are of a dull ivory white.

The young of the green woodpecker, during the first year, may be distinguished from the adult birds by the back being speckled. The whole of the plumage of the young birds is duller than that of the adults.

Three of the genus *Picus* are inhabitants of England—the spotted woodpecker (*Picus major*), the lesser spotted woodpecker (*Picus minor*), and the green woodpecker (*Picus viridis*). The habits of the first two are very much the same as those of the green woodpecker described above.

The black woodpecker (*Picus martius*) and the three-toed woodpecker (*Picus trydactilus*) have been occasionally observed in Great Britain.

DEEP SEA DEPOSITS.

By Rev. H. N. Hutchinson, B.A., F.G.S., *Author of "Extinct Monsters."*

[Second Paper.]

HAVING, in our previous paper, given a general idea of the classification and geographical distribution of deep sea deposits, we now pass on to consider the different kinds somewhat in detail. In the scheme given on page 45 it was shown that, classifying them by their composition, they may be arranged in two groups, (1) Pelagic, (2) Terrigenous. Those of the first group are all organically-formed oozes, except one, the red clay; and may therefore rightly be called pelagic, since they are all born of the sea. Those of the second group are derived from land, or in other words, are products of denudation; hence the term "terrigenous" (earthborn). We will begin with the pelagic deposits. These are generally to be found in situations far from land, and one of them (the red clay) always in the deepest hollows of the ocean bed. Their characteristic mineral particles either have a volcanic origin, or are of secondary origin, *i.e.*, have been formed by some of the wonderful and little known chemical actions taking place on the floor of the deep ocean. Classifications are useful in their way, but are sometimes apt to be misleading, and the reader must be warned against supposing that *no* land-derived material ever finds its way into a pelagic deposit, or *vice versâ*, that *no* pelagic organisms (such as make up most of the oozes) ever enter into the composition of the terrigenous deposits. It is really a question of percentages; and just as a town where the majority vote Liberal may be called a "Liberal" constituency, so a deposit of which the majority (or even a fair percentage) of its myriad individual units or particles are of pelagic origin may be called "pelagic." It is important to bear this in mind, otherwise the scheme of classification alluded to will convey a wrong idea. With the exception of the red clay, all the pelagic deposits are organic oozes *principally* composed of the remains of "pelagic"* organisms that have slowly fallen from the ocean surface, together with some that live on the sea floor. These have received different names, according to the nature of the different organisms of which they are largely composed. Sometimes they are principally composed of the shells of foraminifera, sometimes of the frustules of diatoms, sometimes of radiolaria; and so we have globigerina ooze (taking its name from one of the foraminifera, *globigerina bulloides*, which so largely predominates), diatom ooze, radiolarian ooze, and so on.

Red Clay is the most widely distributed and the most characteristic of all the deep sea deposits (see Chart I., page 44). It covers more than a quarter of the globe's surface. In the Atlantic there are only four patches of it of any great size, but more than half the floor of the Pacific is covered by it. On looking at Chart II. the reader will see that it is spread over the greater depths of the ocean remote from land. In the *Challenger* report seventy samples are described. These ranged in depth from 2225 to 3950 fathoms; average depth, 2780 fathoms. Ever since the red clay was first discovered by the *Challenger* naturalists in depths over 2500 fathoms there has been much discussion and speculation on the subject. Before the present, and perhaps true, theory of its origin was formed, two other views were put forward. As the reader is probably aware, the present theory, due to Mr. John Murray, is that this clay is chiefly derived from the decomposition of volcanic products. Its red colour is due to the formation of ferric oxide and peroxide of manganese from decomposing volcanic material. The rate at which it grows is very much slower than that at which the organic oozes form, and microscopic examination has revealed the interesting fact that cosmic dust from meteorites is one of its constituents. The first theory of the red clay was this: that it is the ultimate product produced by the disintegration of the land—the most finely divided material—which, held in suspension in sea-water, was distributed to great distances by ocean currents. Though this theory has been abandoned there seems to be some truth in it after all; for even Messrs. Murray and Renard admit that some small part of the red clay may be land-derived, or terrigenous. Prof. J. W. Judd, whom we recently consulted on the subject, thinks that this view may be partly true, and that at present it is impossible to determine how much of the deposit comes from the chemical alteration of fine volcanic dust, &c. It may be, after all, that the land-derived débris plays an important part, and that the authors of the report attribute too much importance to the volcanic material.

The second theory may be thus stated: in 1874 Wyville Thomson expressed the opinion that the red clay was primarily of organic origin, being essentially the insoluble residue of calcareous organisms forming the globigerina ooze. But this explanation had to be abandoned because there is no evidence that pure and clean foraminiferal shells contain any appreciable proportion of such mineral matter. It is well known that the surface waters over those deeper parts of the ocean where red clay is found contain an abundance of foraminifera; but these, as we shall see later on, are dissolved in sinking through the deeper waters where there is more carbonic acid in the water. This is clearly proved, because the globigerina oozes gradually pass, as the depth becomes greater, into red clay; and

* Here we are using the word in the sense used by naturalists. Under the designation "pelagic" may be included those forms of life which habitually pass their existence on the free expanse of the ocean, and which only on accidental occasions, if at all, visit the continental borders, or descend (while alive) to the floor of the sea. Messrs. Murray and Renard use the word in a geological or geographical sense by applying it to those deep sea deposits which are for the most part formed either of "pelagic" organisms, or of minute mineral particles, such as floating pumice and fine volcanic dust, which, inasmuch as they are universally distributed over the surface waters of the ocean, may in one sense be also called pelagic. We would, however, point out that it is open to question how far it is wise to confuse the clear and obvious distinction between what is derived from the land and what is derived from the sea. Would it not have been better to place the red clay with terrigenous deposits? They admit that its mineral particles have for the most part a volcanic origin, but M. Renard is inclined to believe that they are due more to submarine eruptions than to the eruptions of land volcanoes. That is a question not yet settled; but surely the word "terrigenous" still applies in either case. If the volcano happens to be a submarine one, that is an accident, but it still belongs to the earth rather than to the sea. We should prefer to see the word "pelagic" reserved entirely for the organic oozes which are truly born of the sea. Particles of volcanic dust and crystals of volcanic minerals, however long they may have been floating about in the sea, are hardly entitled to the term "pelagic." *The sea does not produce them;* so we prefer to consider them terrigenous. The dead body of a sailor floating on the sea, or lying on the ocean bed, could hardly be considered a "pelagic organism," even if it had been shot out of a submarine volcano! Moreover, it is admitted by the authors that "colloid clayey matter from land may play some part in the formation of red clay." This is rather an important question, on which we shall say more presently, but the admission tends to confirm our criticism. Or if, for some reasons, this deposit should appear out of place in the terrigenous group, why not form a transition or intermediate group for it? It is by no means free from organic remains, and in some cases 20 per cent. of it is composed of foraminifera, while radiolaria often form so much of it that it passes into a "radiolarian ooze." Sharks' teeth, ear-bones of whales, fragments of echinoderms, mollusca, &c., are often met with in considerable abundance; still the mineral, as distinguished from organic particles, are its chief feature.

it is easy to trace the gradual rotting away of these shells with increase of depth. Fragments of volcanic minerals are always associated with the globigerina ooze, and, as this fact was ignored or unperceived, it was not unnatural to regard the red clay as something belonging to the ooze itself.

Messrs. Murray and Renard speak of the red clay as a purely chemical deposit, universally distributed in the ocean basins, but often obliterated by admixture with organic oozes, or with mechanical deposits such as mud and sand. It undoubtedly has undergone much chemical change, and in view of this fact, perhaps it would not be a bad plan to class this curious substance by itself as a chemical deposit. We should then have three groups as follows: (1) *Chemical deposit* (the red clay, with its manganese nodules and secondary products); (2) *Pelagic deposits* (all the organic oozes); and (3) *Terrigenous deposits* (muds, sands, gravels, all mechanically formed). By this arrangement we should avoid the difficulty above pointed out, viz., the question how far it has a truly terrigenous origin, like the various muds.

The colour varies greatly in different samples, but red is the prevailing colour, and hydrated silicate of alumina is always present. Sometimes it is brick red, at other times of a chocolate colour, from the presence in great abundance of minute grains of manganese peroxide; and sometimes of a bluish tinge, from the presence of organic matter and sulphide of iron (but only near a continent with large rivers flowing into the sea). The average percentage of carbonate of lime is 6·7, and the amount of lime gets less as the depth increases. Foraminifera may make up as much as twenty per cent. of it; of these some live at the bottom, but the majority are pelagic, and come from the ocean surface. Together with thousands of sharks' teeth (preserved on account of their enamel), and ear-bones of cetaceans, are found numerous large and small fragments of pumice and other volcanic materials; also an abundance, in some places, of manganese nodules. How the latter have been formed we cannot stay to consider now. Remains of pelagic organisms, with siliceous shells or skeletons, are widely distributed in the red clay. When radiolarian remains increase so as to form a considerable part (as in some tropical areas of the Pacific and Indian Oceans), the deposit passes into a radiolarian ooze. When diatom remains (frustules) similarly increase (as in the Southern Ocean) it passes into a diatom ooze; and in other regions, according to the depth, into a globigerina ooze, or even a blue mud. The siliceous spicules of sponges were also found in nearly all the samples.

According to the *Challenger* researches, living organisms appear to be universally distributed over the floor of the ocean; but they are much less abundant on the red clay areas than on any of the other kinds of marine deposits. In the greatest depths, far from land, there is a relative scarcity of life; but even there it cannot be said that nothing lives, as was thought at one time. Star-fishes, echinoderms, foraminifera, &c., have been dredged up from great depths. Fragments of pumice are very widely distributed throughout the ocean floor, varying in size from masses larger than a man's head down to the minutest particles, and they are met with in all states of disintegration—some little altered, others surrounded by zones of chemical alteration; they are often coated with peroxide of manganese. What the authors call "fine washings" (amorphous clayey matter) make up by far the greater part of the red clay and the greater the depth the greater the proportion of the mysterious clayey material. This is an important fact, evidently pointing to long-continued chemical action. The mean percentage of fine washings in the seventy samples reported on was 85·3. The mineral particles are mostly very small—the majority of them ranging from 0·1 to 0·85 millimetre in diameter. In some cases wind-borne particles from neighbouring land have been traced and in other cases ice-borne fragments—for example, portions of ancient continental rocks, such as granite, mica-schist, &c. In the western North Atlantic they were abundantly found as far south as the latitude of the Azores, and must have been brought down by Arctic icebergs which melted as they reached warmer waters. Lastly, the red clay in some localities is found to contain crystals of the class of minerals known as "zeolites," which are the result of certain chemical changes in the material of the clay.

Radiolarian Ooze.—Silica is not nearly so soluble in sea-water as carbonate of lime, and therefore, when the depth is greater than 2500 fathoms (when the foraminifera are mostly dissolved and the red clay begins to be found) and radiolaria abound on the surface, their siliceous skeletons form a large proportion of the material reaching the bottom. So we get a radiolarian ooze. These oozes are confined to the greater depths of the ocean. They resemble red clay in most respects, but differ from it chiefly in containing a much larger number of radiolarian shells, skeletons, and spicules. When a red clay contains twenty per cent. of these beautiful little organisms, so much admired by microscopists, it is classed as a radiolarian ooze. In one sample, from a depth of 4475 fathoms, they formed eighty per cent. Radiolaria seem to be slowly dissolved after the death of the organisms that secrete them from the silica contained in sea-water, for the skeletons and spicules are often seen to be reduced to the merest threads. Siliceous organisms average 54·4 per cent. The average depth at which the deposit occurs is 2894 fathoms.

Readers who live in London should pay a visit to the splendid Natural History Museum, and inspect the beautiful models in glass of the radiolaria, near the corallines. How they have been made is a puzzle to the writer, so exquisitely fine are their long threads.

Diatom Ooze.—Diatoms are also well known to microscopists. These organisms, which belong to the vegetable kingdom, abound in cold seas and estuaries. Their cases, or frustules, show structures of great beauty. The ooze that takes its name from them is found at all depths in the Southern Ocean. When dried it is nearly pure white. [A huge lump, obtained from the bed of a lake, may be seen in the Botanical Gallery of the Natural History Museum.] Marine diatom oozes contain about fifty per cent. of diatom frustules, mixed with radiolaria, sponge spicules, together with ten or twenty per cent. of carbonate of lime. A great zone of this ooze, of varying width, surrounds the south polar regions, and covers over 10,800,000 square miles. The low temperature of this region accounts for the small proportion of foraminifera, &c. it contains, for the lime is only ten to twenty per cent. The presence of a good deal of terrigenous matter in this ooze proves the existence of an unknown ice-covered continent round the South Pole. *(To be continued.)*

THE DISTRIBUTION OF THE STARS.

By Miss A. M. Clerke, *Authoress of "The System of the Stars" and "A Popular History of Astronomy during the Nineteenth Century," &c., &c.*

THE fundamental difficulty of stellar astronomy is that of rightly inferring the real from the projected places of the stars. Prolonged study is needed to show that they are not scattered at random over the sky. They shine down upon us as if flung loosely over the surface of a sphere, and indeed owe their

name of "fixed" stars to the crude early notion of their being rivetted—*infixæ*—to the "palace-roof" they very effectually serve to adorn. Yet in reality this starry vault integrates, so to speak, immeasurable abysses of star-strewn space. There, as elsewhere, "things are not what they seem," and we are confronted with the inevitable question as to the relation between the thing that is and the thing that seems. From the aspect of the Milky Way came the first suggestion of an answer. The thought could not but present itself to intelligent inquirers that the dimly-shining girdle of the sphere might exercise a governing influence over its contents. Varied investigations of this obvious possibility were accordingly carried out, and the fact was established of a general increase of stellar density, gaining intensity with descent in magnitude, towards the galactic plane. The combination into a system was thus rendered probable of the sprinkled stars of the constellations and the streaming stars of the nebulous zone running through them; but no hint could be gathered as to the nature of the combination. Only the bare existence of some principle of arrangement was perceived by unsatisfactory glimpses.

Until lately the only practically available means of searching out the plan of stellar structure was by instituting comparisons between the numbers and the magnitudes of the stars. Average brightness, it was reasonably supposed, gave a measure of average relative distance, and from distance relative abundance per unit of space could be inferred by simply counting the successive photometric ranks. But the value of this method has been impaired by an advance of knowledge in two directions. In the first place it became evident, on a wider acquaintance with stellar proper motions, that their assorted amounts afforded a much surer test of distance than could be derived from the consideration of magnitude alone. Next, it came to be recognized that the intrinsic brilliancy of stars is very different for different spectral types, so that stars of the Vega type must be nearly three times more remote than stars like Capella or the sun, equally massive, and possessing the same visual brilliancy. Diversity of stellar type implies then, diversity in laws of distribution—diversity, not only of the photometrical, but also of the physical kind, and hence constituting an essential feature of sidereal organization. The preponderance of Sirian stars in the Milky Way, simultaneously ascertained during the progress of Prof. Pickering's spectographic survey and of Dr. Gill's photographic Durchmusterung, appears to be a combined result. In part, it must depend, as pointed out by Mr. Monck, upon the crowding in of Sirian stars lying far beyond the limiting distance of the included solar stars; but there is reason to believe that it is also in part produced by a genuine relationship. What is certain is that it fits in with much that was already known, and provides a fresh platform for further inquiry.

It was in great measure through the labours of Prof. J. C. Kapteyn, of Groningen, in measuring and reducing the Cape Durchmusterung plates, that the systematic difference in question was detected; and their conclusion has allowed him leisure to follow up the clue thus placed in his hands. He has done so by a research into the distribution of the stars, with special reference to their spectral types, communicated to the Amsterdam Academy of Sciences in two important papers, read April 29th, 1892, and January 28th, 1893, respectively. The first, indeed, gave only preliminary inferences, but they were ratified and extended in the second by the discussion of a greatly enlarged stock of data. These related to 2357 stars, of which 1189 are classed in the Draper Catalogue of Stellar Spectra as of the first, 1106 as of the second, and 62 as of the third type. The proper motions of 476 of them were taken from the list prepared by Herr Stumpe for his determination of the solar translation; those of the rest from the Bradley-Auwers catalogue. The treatment of this material was on the principle that stars are, on a fairly wide average, distant from us in the inverse ratio of their apparent movements. So far as concerns the perspective element contained in them, this is of course strictly true, allowance being made for differences of angular position with regard to the apex of the sun's way. That is to say, the line traversed in a given time by the sun, if seen *square* from any star, would be of a length proportionate to that star's remoteness; and the transferred displacement of the star, as viewed from the sun, would be equal and opposite to the proper displacement of the sun as viewed from the star. Thus, assuming the direction of the solar translation known, and the "peculiar" movements of the stars to be so irregular as to give a zero effect when numerously thrown together, a secure measure is afforded of comparative stellar distance. Prof. Kapteyn accordingly resolved his proper motions into two components, one directed along a great circle passing through an apex in R.A. 276°, Dec. + 34°, the other at right angles to it. The first, reduced to a position 90° from the apex, was treated as of wholly perspective origin; the second could not but be wholly original. And it was reassuring to find that their values (abstraction being made of a few exceptionally swift objects) varied in groups of stars arranged according to proper motion, pretty nearly in the same proportion. Either component, then, of stellar motion—the parallactic, or the peculiar—appears to supply a valuable criterion of stellar distance.

The initial difficulty connected with space-sounding operations being thus removed, a number of interesting conclusions lay, comparatively speaking, close at hand. Some of these had been anticipated by Mr. Monck, and their independent deduction, through a far more elaborate investigation, shows them to be deserving of no small credit. To begin with, the remarkable circumstance seems fully established that stars with well-accentuated proper motions show predominantly spectra of the solar description.* Nor can we hesitate to agree that these objects owe their mobile character to their relative vicinity. They constitute, accordingly, a group which surrounds and includes the sun. It is most likely roughly spherical in shape, and is so strongly condensed interiorly that a volume of space near its centre contains 98 times as many stars as an equal volume near its circumference. The maximum compression appears to be round a point† lying away from the sun, towards the north-western section of Andromeda, supposed by Prof. Kapteyn to coincide with the centre of the Milky Way. But this identity is highly questionable. It depends—since the centre found for the cluster has a southern galactic latitude of about 20°—upon the truth of Sir John Herschel's and Struve's respective inferences of a position for the sun, eccentric as regards the round of the Galaxy, and to the north of its medial plane. The brilliancy of the Milky Way, however, in the southern hemisphere affords in reality not the slightest presumption of nearness‡; and Gould was unable, from a much more complete inquiry than Struve's could possibly be, to assign to the sun either north or south galactic latitude. His situation, for anything that can be proved to the contrary, may be perfectly symmetrical within the great cosmical annulus. It cannot then be admitted, at least on the present showing, that the latter is concentric with the newly-constituted solar star-

* See Ranyard, KNOWLEDGE, Vol. XIV., p. 50; "Old and New Astronomy," p. 798.

† The co-ordinates of which are R.A. 0h. 0m., Dec. + 42°.

‡ Sutton, KNOWLEDGE, Vol. XIV., page 42.

group, which, it may be remarked, has little or nothing in common with "Gould's cluster." This is projected in the form of a belt, and is largely made up of Sirian stars with slight or inappreciable proper motions; while Prof. Kapteyn's collection shows no preference for the galactic, or any other plane, and includes only a slight sprinkling of "white stars," such as Vega, Sirius, Altair, and Regulus, admitted because of the vicinity implied by their motions.

Beyond a certain limit of distance (estimated by proper motion), both Sirian and solar stars exhibit marked condensation towards the plane of the Milky Way. The former, indeed, much more than the latter; yet even solar stars, when remote enough to be sensibly stationary,* obey the law of galactic attraction to an equal extent with the whole body of stars down to the ninth magnitude. The distribution, accordingly, of second type stars is apparently regulated by two distinct principles; and the first, that of globular aggregation about the sun, acts altogether independently of the second, that of galactic thronging. But how the sphere and the stratum resulting severally from the two kinds of influence are related, whether they are contiguous or widely separated, we have no means of determining.

Stars of the first type are more equably distributed. They are at least exempt from the tendency of their correlatives to concentration in the neighbourhood of the sun. On the other hand, they are drawn more strongly towards the Milky Way. They accumulate mainly into a disc, or possibly into a series of rings. The proportion of their numbers to those of second type objects grows rapidly with increase of distance. Outside a sphere, of which the radius corresponds to an annual proper motion of 0·07″, they are in a minority smaller and smaller as its centre is approached; outside of that sphere they claim about a two-fold numerical superiority. But is the superiority real or fictitious? We seem obliged to adopt the latter alternative. The disparity can, at any rate, be amply accounted for by the systematic difference in real brightness between the two great stellar orders.

Prof. Kapteyn holds that there is no satisfactory evidence of their differing systematically in real swiftness. He has investigated the matter with a negative upshot. At equal distances, he finds Sirian and solar stars to be pretty equally displaced. The balance, that is to say, does not so far incline decisively either way. But at equal distances Sirian stars appear brighter by more than two magnitudes than solar stars of similar mass. To send us the same quantity of light, they must then be 2·7 times more remote. Hence, obviously, an indiscriminate collection of stars exceeding a given magnitude represents the contents of a far larger volume of space as regards the first than as regards the second stellar order.† If the latter be included in a sphere of mean radius=1, the former must be diffused through a sphere of radius=2·7. The true proportion of their numbers, as compared with solar stars, would accordingly be increased in such a collection not far from twenty times! And the chief part of these adventitious stars, if they may be called so, would naturally fall into the ranks of immobile objects. To their presence, then, the excess of first type spectra among the Bradley-Draper stars with evanescent proper motions may safely be attributed.

The leading results of Prof. Kapteyn's able and exhaustive discussion may be recapitulated in the two following propositions:—

1. Stars with appreciable proper motions belong mainly to the solar spectral class, and gather round a point adjacent to the sun, in total disregard to the position of the Milky Way.

2. Stars sensibly fixed, Sirian and solar alike, although not to the same extent, collect towards the galactic plane. Both types can hence be inferred to obey the same organic laws, and to be united into a coherent whole.

An unexpected peculiarity of distribution, indicated by this investigation, if not convincingly proved by it, is that stars of determinate magnitude of either type are on the whole more remote when situated in or near the Milky Way. It can only be explained as due to a greater prevalence of larger or more luminous bodies in that region than in other parts of the sky.

The general shape of the stellar universe is compared by Prof. Kapteyn to that of the Andromeda nebula, as depicted in Mr. Roberts's photographs. The globular nucleus represents the solar cluster, the far-spreading rings or whorls the compressed layers of stars enclosed by the ring of the remote Galaxy.

[Prof. Kapteyn's conclusion that Sirian stars appear brighter by more than two magnitudes than solar stars of similar mass is very interesting in connection with the evidence we already possess as to the relative density of Sirian and solar binary stars. The tables given on pages 796–7 of "The Old and New Astronomy" give 0·3094 as the mean density of the binary stars of known period whose spectrum is of the solar type, and 0·021 as the mean density of the binaries of known period whose spectrum is of the Sirian type—that is, solar binaries are on the average about fifteen times as dense as Sirian binaries.

So that, if Sirian stars and solar stars have photospheres of equal brightness, the Sirian stars will have on the average a diameter nearly two and a half (2·466) times as great as the diameter of solar stars of the same mass, and they would appear equally bright to us if situated at 2·466 times the distance of similar solar stars. In other words, the evidence derived from binary stars shows that Sirian stars appear to us nearly two magnitudes brighter than solar stars of similar mass.

Prof. Kapteyn's general result seems to me to be involved in his assumption that proper motions are to be taken as the criterion of distance. This seems to me to involve the assumption that all types of stars are moving with the same average velocity, an assumption which is not self-evident, but which seems, on the contrary, improbable in view of what we know as to certain types of stars being associated in clusters. Such clusters evidently form systems, and the individual stars cannot therefore have large proper motions relatively to one another, for such motions could not be controlled by the mutual gravity of the stars forming the system.

A solar cluster of swift-moving stars, such as Prof. Kapteyn supposes, could not form a permanent system. The vast velocity which we know that our sun and other stars having large proper motions are endowed with would carry them away from the centre of gravity of such a system, if it was composed only of the swift-moving bright stars we see. Their swift motions cannot be controlled by one or more dark stars of enormous mass, for the places of such dark attracting masses would be indicated by the symmetry of the motion of the bright bodies about them; and it is evident that such a solar cluster could not be held together by the attraction of rings of matter outside it.—A. C. Ranyard.]

* With proper motion, that is to say, smaller than 0·04″.

† This mode of reasoning has been anticipated by Mr. Monck.

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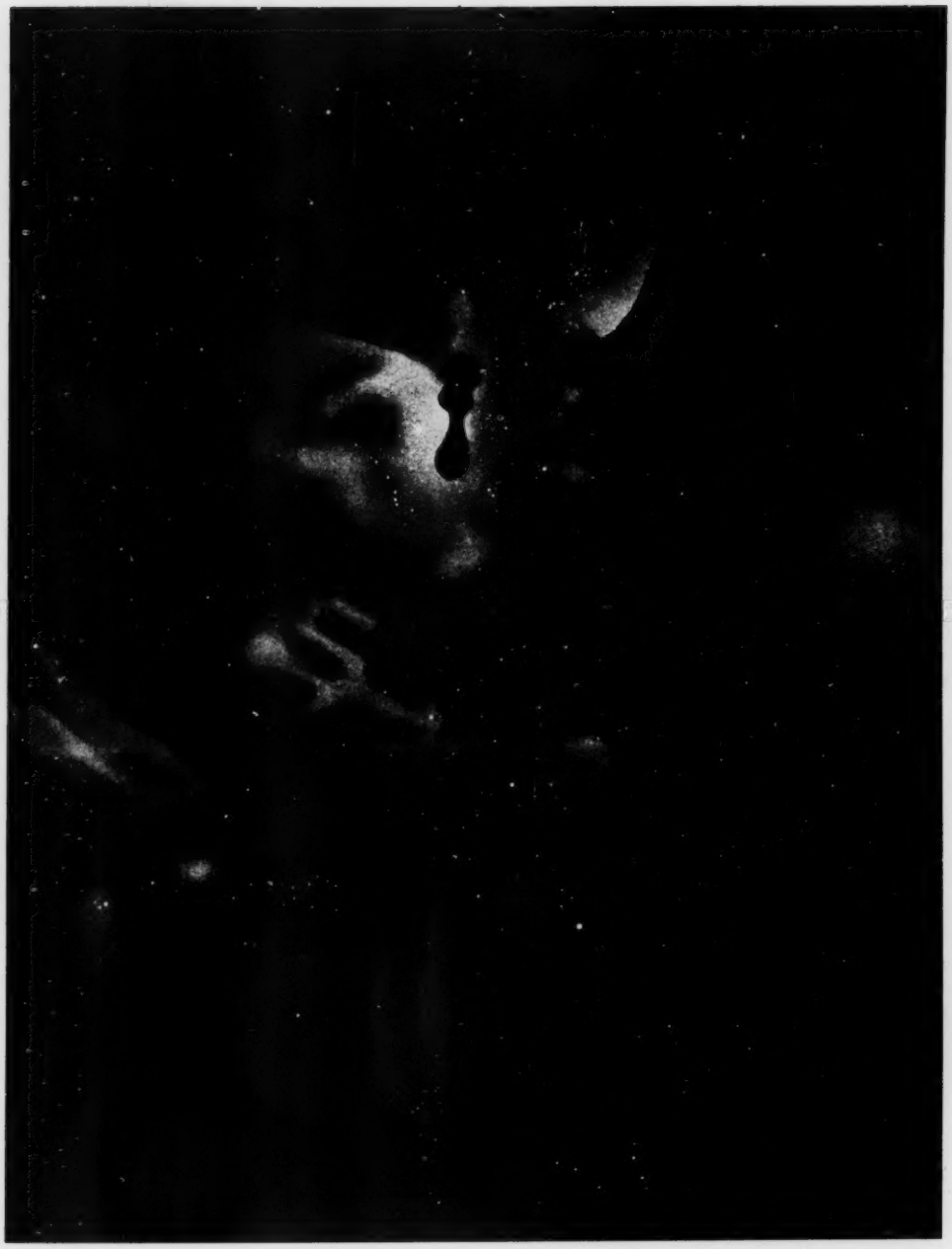
NORTH.

Following.



Preceding.

SIR JOHN HERSCHEL'S DRAWING OF THE GREAT NEBULA ABOUT η ARGÛS
as seen with his 24 feet Reflector at Feldhausen, Cape of Good Hope, in the years 1834 to 1837.

The drawing has been copied from the plate in the "Cape Observations." It has been reduced so as to correspond in scale with the plates from Mr. RUSSELL's and Dr. GILL's photographs. Sir JOHN HERSCHEL having observed with a Newtonian Reflector, it has been necessary to reverse his drawing right and left, so as to make it correspond with the photographs. The divisions are not the same as those of the Reticule on Dr. GILL's photograph.

Direct Photo Engraving Company, 9, Barnsbury Park.

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THE η ARGÛS NEBULA.

By A. C. Ranyard.

WE are indebted to Dr. Gill for the very beautiful photograph of this nebula, which we are enabled to present this month to our readers, for comparison with the photographs of Mr. Russell published in last month's number of Knowledge, and with the drawing of the nebula laboriously made by Sir John Herschel during his visit to the Cape in 1834-38.

On first comparing the drawing with the photographs, probably most of our readers will fail to recognize much similarity; but, on closer inspection, many of the striking features of the nebula as shown in the photographs will be recognized as having certainly been seen by Sir John Herschel. For example, the dark oval space, shaped like a "kidney bean," shown in the lower part of Sir John Herschel's drawing, to the right of the centre, is distinctly recognizable on Dr. Gill's photograph. It is to be found in the horizontal rows of squares marked out by the reticule which have been numbered 5 and 6, and in the vertical column of squares marked 26. That this is the dark patch which was noted and attempted to be drawn by Sir John Herschel is evident from the stars which surround the dark region. The positions of these stars were carefully measured, and their magnitudes were noted and repeatedly compared by Sir John Herschel. Two of the brightest of them are on the south following side of the dark patch, and lie just upon the edge of the nebulosity. There is also a line of stars which lie upon the preceding side of the dark patch, and seem to coincide with and mark out the limit of nebulosity. The brightest of the stars on the preceding side of the dark area is at its northern end, and lies just within the nebulosity.

It will be noticed that these stars, though they agree satisfactorily in position with the stars given in Sir John Herschel's drawings, differ so materially in their relative magnitudes that we are forced to conclude either that many of the stars are variables, or that the photographic magnitudes (which agree on comparing Dr. Gill's photograph with Mr. Russell's) do not at all correspond with the visual magnitudes. A similar remark applies to the four stars shown in Sir John Herschel's drawing on the following side of the pair of stars bordering the south following edge of the dark oval area.

Another feature of Sir John Herschel's drawing of the nebula, which is distinctly recognizable in the photographs, is a narrow dark channel which runs north and south near to the centre of the lower (or southern) part of Sir John Herschel's drawing. This will be found in Dr. Gill's photograph on the preceding side of the vertical column of squares numbered 23, and extending from the horizontal row numbered 7 to horizontal row 5. The stars at the southern end of this dark channel on the Herschel drawing can, with difficulty, be recognized on the photograph, but a group of stars forming two closed curves on the north following side of the dark channel can be distinctly recognized on the photograph, in columns 22 and 23, row 8. In this region the nebulosity, as drawn by Sir John Herschel, entirely differs from the photographs.

One of the most striking features of Sir John Herschel's drawings, which is not shown in the photographs, is a curious trident-shaped structure on the following side of the centre of the Herschel drawing. The upper part of this structure has been compared by Dr. Gill to the figure of a swan, but although it is one of the brightest structures in the lower half of Sir John Herschel's drawing, there seems to be no nebulosity corresponding with it in position on the photographs which, on the hypothesis that there has been no change in the nebula since 1834, could have been represented by Sir John Herschel by this swan-shaped structure. Its place on Dr. Gill's and Mr. Russell's large photograph is nearly free from all nebulosity—and even on Mr. Russell's very dense photograph taken with his Dalmeyer 6-inch lens, which was reproduced in the last number of Knowledge; though there is a general faint nebulosity in the corresponding region, there is no trace of the curving form drawn by Sir John Herschel.

The question whether we are warranted in assuming that a change of such magnitude has taken place in the nebula in a period of less than sixty years is one of great interest. The structure we are considering measures about seven minutes across its smaller diameter, and even if we assume that the nebula is not at a greater distance from us than our nearest neighbour amongst the stars (α Centauri), the diameter of the structure would be equivalent to 280 times the diameter of the earth's orbit, or to more than nine times the diameter of the orbit of Neptune; consequently, the disappearance of such a structure would involve either a change of brightness of the matter distributed over an enormous space, or a very rapid motion of the nebulous matter. The swiftest-moving star we know (1830 Groombridge) would only move across a space equal to the diameter of the missing structure in sixty years.

A series of observers have examined the nebula since Sir John Herschel's drawing was published, and have noted changes which they believed could not be explained by inaccurate draughtsmanship, but it seems to me that their drawings differ as much amongst themselves as Sir John Herschel's drawing differs from the photographs. The difficulty of accurately drawing an object like a nebula, which cannot be sketched with definite outlines, can only be realized by those who have made an attempt to represent a nebula or a corona or other object where the likeness or want of similarity depends upon the due graduation of tints, and where an alteration in the intensity of the brightness of any area frequently involves a corresponding alteration in the tints representing the brightness of surrounding areas. In a question of such importance I prefer to wait until we have the unbiassed evidence of photographic plates taken at long intervals, before admitting that there is undoubted evidence of changes rapidly taking place on so gigantic a scale.

The following list of papers on this nebula may interest those who desire to examine more closely the evidence we already possess with regard to changes which most of the observers who have given their attention to the nebula believe are rapidly taking place within it. I am indebted to my friend Mr. Sadler for several of these references.

1834-1838.—Sir John Herschel, "Cape Observations," pp. 32-47.
1861-1864.—Mr. F. Abbott, of Hobart Town, Tasmania, *Monthly Notices*, xxiv., pp. 2-5.
1863-1868.—Mr. F. Abbott, *Monthly Notices*, xxviii., pp. 200-202.
1870-1871.—Mr. F. Abbott, *Monthly Notices*, xxix., pp. 226-234.
1871.—Captain J. F. W. Herschel, *Monthly Notices*, xxix., p. 235.
1854-1870.—Mr. J. Tebbutt, *Monthly Notices*, xxiv., p. 211.
1871.—Mr. H. C. Russell, "Transactions of the Royal Society of New South Wales for 1871," pp. 15-24.
1869-1871.—Mr. F. Macgeorge, "Transactions of the Royal Society of Victoria," vol. x., pp. 106-113. [This paper contains drawings by Mr. Le Sueur, as well as by Mr. Macgeorge.]
1882.—Mr. C. E. Peek, "Rousdon Observatory Observations for 1882-5." [Contains a drawing of the nebula, made by Mr. Peek at Jimbour, Queensland.]
1891.—Mr. H. C. Russell, *Monthly Notices*, li., pp. 494-497.

Most of these observers have given special attention to the region in the northern nebulous mass around the dark opening which, in Sir John Herschel's drawing, looks like a keyhole. He refers to it in the "Cape Observations,"

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p. 38, as "a singular lemniscate-oval vacuity," and says that a thin nebulous veil extends over a part of its area on the preceding side. In the photographs it appears much narrower, and with a form which reminds one of a solar prominence. This is no doubt the blackest and densest part of the dark area drawn by Sir John Herschel. That there still exists a wider dark area with an outline somewhat similar to that drawn by Sir John Herschel is evidenced by the drawing of Mr. Peek made in 1882, as well as by the drawing of Mr. Le Sueur made in 1862, given in Mr. Macgeorge's paper.

In the photographs several narrow, somewhat similar curved structures will be noticed extending into the northern nebulous mass. They should, in the first instance, be looked for on Dr. Gill's photograph, and should then be examined on the less dense photograph of Mr. Russell published in the March number of Knowledge. The largest lies a little to the north of Herschel's lemniscate structure, and is situated in column 24 and row 14. It seems to extend downwards from an area about two bright stars, and it has a spreading and branching head like the largest of the structures which has attracted the attention of all observers. A third of these curving structures is cut by the line of the reticule between rows 13 and 14, on the south preceding side of the great nebulous mass. It, too, seems to have a branching head and a curving stem, which is broadest and darkest near its base. A similar but rather smaller dark branching structure will be found in row 14, column 26, and another in row 15, column 26, entering the great nebulous mass from its north following side, and again another on the south preceding side of the great nebulous mass in row 12, column 25.

The appearance of many of these smaller dark structures is somewhat similar to the appearance which the largest lemniscate structure of Herschel assumes on the dense photograph taken with Mr. Russell's camera, which was reproduced in the March number and faces his larger photograph. In the camera photograph it will be noticed that the great lemniscate structure is reduced to a very narrow, dark, almost linear structure; this may possibly be due to the irradiation and encroachment of the brighter parts caused by the want of sharpness in the image thrown by the short-focussed camera lenses, or it may be due to the partial transparency of the edges of the dark structures. That the dark structures are partially transparent is, I think, rendered evident by a comparison of them as shown upon Dr. Gill's photograph and Mr. Russell's less dense large photograph published in the March number. In the latter photograph they appear broader and far less sharply defined at their edges than in Dr. Gill's photograph.

The connection between the dark areas in this nebula and alineations of stars along their borders was noticed by Sir John Herschel. Such bordering lines of stars are noticeable about the dark area that lies in rows 5 and 6, column 26, which has been referred to as being shaped like a "kidney bean." A similar bordering of a dark area by lines of stars is noticeable about the dark structure which lies in row 13, columns 28 and 29, and there are also very evident lines of stars along the borders of the broad dark channel on the south preceding side of the northern nebulous mass.

Some light may be thrown on the nature of the dark structures in the Milky Way by the forms they assume in this nebula. The prominence-like dark forms all appear to spring from the outside of the bright masses, and to be projected into the brighter matter. In the nebular mass to the north of the trifid nebula (a photograph of which was published in the January number, 1893) three dark prominence forms seem to spring from two central dark patches within a bright nebulous cloud. Similarly, in the photograph of the Sagittarius region, published in the December number of Knowledge for 1891, three dark branching structures appear to spring from a dark area surrounded by bright stars and star clusters at the lower right-hand corner of the picture. In the region about α Cygni, a photograph of which was published in the October number of Knowledge for 1891, the dark branching structures (with the exception of the tree-like structure to the north of α Cygni) seem to spring from the dark region on the following side of α Cygni, and the tree-like structure to the north of α Cygni is connected with a long dark channel running east and west upon the plate, and associated with lines of stars. In all these cases the dark structures seem to represent matter projected into a resisting medium.

There are many ways of accounting for an opaque or partially opaque cloud in space. We have, in the chromosphere of our own sun, dark prominence forms, which are occasionally seen, and have been photographed by Prof. Hale. These, we have reason to believe, are due to cool masses of gas cutting out the light derived from similar incandescent gas behind them. But in the case of the Milky Way it seems more probable that we have to deal with matter at a lower temperature than that in the solar chromosphere, and it seems reasonable to suppose that such moving streams of gas would be derived from a heated source, and would be hotter than the medium surrounding them. We have, therefore, to account for an opaque condition of matter when it is comparatively hot, and a luminous condition as it cools.

A mass of mixed gases and vapours, on expanding and radiating into space, would no doubt, in the first instance, be precipitated into very fine particles surrounded by gaseous matter corresponding to the materials which only condense at a still lower temperature. The transparency of such a cloud would depend upon the size of the particles into which the less volatile constituents were precipitated, and on the distance between such particles. The amount of matter in a unit of volume remaining unchanged, the smaller the particles into which the matter condensed the more opaque would be the cloud; thus, if the earth were broken into cubical masses an inch in diameter, which were distributed uniformly throughout a sphere with a diameter as large as the diameter of the earth's orbit, and the sun were situated at the centre of such a spherical cluster of stones, it may be shown that only about half his light would emerge from the cluster. If the fragments were very irregular in shape, though of the same average weight as before, a larger proportion of the sun's light would be intercepted; and if the stones were broken into fragments as large as sea sand, a planet outside such a cluster would revolve in practical darkness. It is evident that a cloud or fog of precipitated particles would become more and more transparent as condensation and aggregation of the particles went on.

The microscopic structure of meteors seems to indicate that they originally consisted of minute separate particles, which have become aggregated and cemented together. As such aggregation went on, a cloud of meteoric matter would become more and more transparent, and the uncondensed gaseous residue would tend, as it cooled to a low temperature, to collect around such meteoric bodies in loosely packed atmospheres. I assume that the incandescence must be caused by occasional impacts between such atmospheres, which, if the meteors are moving, must come into collision much more frequently than the meteoric bodies themselves.

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PHOTOGRAPH OF THE η ARGÛS NEBULA.

Taken by Dr. GILL, at the Royal Observatory, Cape of Good Hope, with the Astro-Photo-telescope of 13 inches aperture used for the International Survey of the Heavens. Enlargement, 6¾ in. = 1°. Exposure, 12 hours 12 minutes on four days, March 26th to March 30th, 1892. The squares are produced by the Reticule used for the International Survey photographs.

Direct Photo Engraving Company, 9, Barnsbury Park.

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Science Notes.

In the *Astronomical Journal* (Nos. 285-86), Prof. Barnard gives the results of a series of observations of Jupiter's fifth satellite. The period of revolution is found to be 11h. 57m. 23·06s. "The hourly motion of the satellite is 30° 11′, and the velocity in its orbit about 16·4 miles a second, which is some twelve times as rapid as the motion of Phobos, the inner satellite of Mars. The horizontal equatorial parallax of the new satellite is 21° 61′. The distance from the surface of Jupiter is about 67,000 miles. The satellite seems equally bright at the eastern and western elongation. No amount of magnifying power has shown it other than as a stellar point. Its shadow cannot be seen in transit." From new determinations the following values were adopted for the Jovian diameters :—

Equatorial diameter 89,790 ± 65 miles.
Polar ,, 84,300 ± 80 miles.

The values given in Young's "General Astronomy" are 88,200 and 83,000 miles respectively.

The determination of the period of the new satellite by Prof. C. A. Young, given in our last number, was by mistake printed 11h. 57m. 4s.; it should have been 11h. 57·4m., the 4 being a decimal and equivalent to 24s., which corresponds very exactly with Prof. Barnard's determination.

According to Mr. Harold Jacoby, "the Rutherford photographic measures of the stars about β Cygni, contained in the sixth volume of the *Annals of the New York Academy of Sciences*, exhibit certain discordances which can be explained on the hypothesis of a large parallax for β Cygni, amounting to nearly a whole second of arc. The evidence cannot be regarded as conclusive, but Mr. Jacoby thinks that it is sufficiently strong to make this star an object of especial interest and promise to parallax-observers." Measures taken from six negatives give 0·97″ as the parallax of the star. The parallaxes of μ and θ Cassiopeiæ, also deduced from Rutherford's photographic measures, are 0·275″ and 0·232″ respectively.

Our knowledge of the solar corona would no doubt advance more rapidly if a means could be devised of photographing it in ordinary daylight. Recently the matter has been taken up again by M. Deslandres, of the Paris Observatory, and Prof. George E. Hale. The former observer passes sunlight through two prisms having their faces parallel, but with the base of one opposite the refracting edge of the other. If the whole spectrum formed by the first prism pass through the second the sunlight is recomposed into white light; but by placing the prisms some distance apart only a portion of the first spectrum traverses the second prism, and a coloured image of the sun is obtained. The colour of this image can be changed by rotating the first prism; but at present no region of the spectrum has been found in which the light of the corona is so much greater than diffused daylight as to permit the corona to be seen or its image to be registered upon a photographic plate under ordinary circumstances. Prof. Hale thinks that the best results will be obtained by using ultra-violet rays in future photographic experiments, for there is some reason to suspect that the brightness of the corona with respect to the surrounding sky is inversely proportional to the wave-length of the light employed for the observation. Prof. Hale will shortly try an instrument, similar to the spectro-heliograph, which has been constructed for the express purpose of photographing the corona.

The Actonian prize of one hundred guineas, which is awarded by the Committee of Managers of the Royal Institution every seventh year, has been given this year to Miss Agnes M. Clerke for her works on Astronomy. The recipient in 1886 was Sir George Stokes for his little book on "Light."

A society has recently been formed for the purpose of furthering the study of the Mollusca and Brachiopoda. It is to be called the Malacological Society of London, and its meetings are to be held monthly, at eight o'clock in the evening of the second Friday in the month, at 67, Chancery Lane. Dr. H. Woodward is to be the first President.

Dr. Scott, in his latest experiments on the proportion in which hydrogen combines with oxygen to form water, finds that the ratio of hydrogen to oxygen is not 2 to 1, but more than 2 volumes of hydrogen to 1 of oxygen. The exact ratio is 2·00246 hydrogen to 1 oxygen. This result has an important bearing on the determination of the atomic weights of the elements, the exact value for the atomic weight of hydrogen not being known with reference to other elements, such as oxygen.

Mr. Boys with his radio-micrometer can observe a deflection of the instrument, which is due to a temperature difference of less than one two-millionth ($\frac{1}{2000000}$) of a degree Centigrade. In one particular case the surface receiving the radiant heat is a disc only 2 millimetres in diameter, and when the scale is 30 inches from the mirror, the hand held about a yard from the instrument produces at once a deflection of 16 centimetres, shown by the spot of light thrown by the mirror on the scale. Mr. Boys also calculates that the heat received by a halfpenny at 1500 feet from a candle flame would, if concentrated on the sensitive surface, produce a readable deflection.

Mr. J. W. Salter, writing to the *Zoologist* from University College, Aberystwith, says that on January 4th last he obtained a polecat about six miles south of Aberystwith. He thinks that there is reason to believe the species is by no means extinct in Cardiganshire.

In *Nature* for February 23rd Dr. Ball gave an interesting account of lion-tiger hybrids. In the next number Mr. S. F. Harmer, of Cambridge, draws attention to the fact that his university possesses the skeleton and stuffed skin of an *adult* hybrid between a lion and a tigress. It was about six years old, and although inferior in size to either of its parents, the animal appeared to have attained its full dimensions. The shape of the head resembled that of the father (the lion), whilst the form of the body was more similar to that of the tigress. The body was faintly striped. It was a female and had neither a mane nor a tuft at the end of its tail.

The *Times* recently gave an account of a process by which anthracite coal bricks are now being manufactured. Grains of anthracite dust are forced together, partly by means of a cementing compound and partly by great pressure. The coal dust is mixed with the binding material in the proportion of ninety-six per cent. of the former to four per cent. of the latter. These coal bricks are said to make an excellent fuel, and to possess a very high efficiency for steam-raising purposes. Should this fuel be largely used for household purposes, it is to be hoped that the atmosphere of our towns will be less smoky.

XUM

The idea that water on freezing gets rid of its impurities turns out to be another instance of a popular fallacy. Recent careful experiments show that the average amount of impurity retained by ice is 34·3 per cent. of organic matter and 21·2 per cent. of inorganic matter. In view of these results it behoves those who supply ice to shops to exercise some care as to the source from which it comes.

A translation of Prof. Weisman's "Das Keimplasma" (the Germ Plasm) has been issued in "The Contemporary Science Series" (Walter Scott). The translators are Prof. W. N. Parker and Harriet Rönnfeldt, who have done their work carefully. Prof. Parker has had the great advantage of being able to consult Prof. Weisman personally with regard to many of the more difficult passages.

An important paper on "Fossil Mammals of the Wahsatch and Wind River Beds," by H. F. Osborn and J. L. Wortman, has been issued as a bulletin by the American Museum of Natural History, and has also been published separately. It is principally devoted to a description of a collection made by Dr. Wortman during the summer of 1891. The authors claim that many new facts of great interest are brought out by the material in the collection.

M. Moissan, the eminent French chemist, who succeeded a few weeks ago in producing diamonds artificially, contributes to the *Comptes Rendus* of March 6th some further observations on the chemical properties of the diamond. He finds that the temperature of combustion of diamonds in oxygen varies with different specimens from 760° C. to 875° C. In general, the harder the diamond the higher is its temperature of combustion. Dry chlorine and hydrofluoric acid vapour are incapable of acting upon the diamond until a temperature of about 1200° C. is reached. At this temperature, however, fused carbonates of potassium and sodium easily dissolve it, carbonic oxide being evolved by the reaction.

Dr. Bashford Dean, who was sent by the United States Fish Commission in 1891 to study the cultivation of the oyster in Europe and America, has just issued two reports (*Bulletin U.S. Fish Comm., 1890*), one dealing with "Oyster Culture in France," the other with the "Natural Oyster Grounds of South Carolina." The first report shows the very high state of perfection to which the cultivation of the oyster has been brought in France. The second report deals in the fullest manner with the natural conditions affecting the growth, the nature of the bottom, the food, enemies, &c., of the South Carolina oyster, and is illustrated by reproductions of photographs.

The *Geological Magazine* for February contains an instructive sketch of the life and work of the late Sir Richard Owen from the facile pen of the editor, Dr. Henry Woodward, who was his official colleague during a quarter of a century. We will only quote the following paragraph:—"The success that attended him in his long life resulted from a combination of circumstances. Everybody will readily admit the fact of Professor Owen's extraordinary genius, his sagacity in interpretation, and his remarkable ability as a lecturer; but behind these he owed very much to his indomitable energy and power of sustained work, to his marvellous flow of language, to his vigorous bodily health, and, in controversy, not a little to his cleverness both in defence and attack. His courteous manners, when dealing with the general public, were proverbial, and also the marked attention which he paid to the rank of the individual."

The Rev. F. J. Smith, Millard Lecturer at Trinity College, Oxford, points out in *Nature* of March 9th that an efficient screen from the magnetic influence of a large dynamo is obtained by building two brick walls a short distance apart and filling the interspace with scrap iron. A screen of this character has been constructed to protect the physical instruments of the Millard Laboratory from the intense magnetic field of the transformer of the Oxford Electric Lighting Company, and it answers the purpose extremely well.

The Commission appointed to investigate the subject of electrical communication with lighthouses and lightships has recently finally considered an *ad interim* report. This report deals with that portion of the evidence relating to the necessity of establishing telegraphic communication with lightships and lighthouses on the British coast. It is understood that the Commissioners recommend experiments being made in the matter of direct communication between lightships, &c., and the shore upon some of the most dangerous shoals and sands.

For some time M. Mascart has used, under the name of a *gravity-barometer*, an instrument by means of which the variation of gravity between different places can be determined. The instrument has recently been employed in determining whether there are temporary variations of gravity in one and the same place, and M. Mascart finds anomalous disturbance, which he is unable to attribute to changes of temperature or other physical changes affecting the instrument. He is inclined to treat them as evidence of variation in the force of gravity, and it is pointed out that observations of this kind will no doubt present a peculiar interest in volcanic districts if the changes are due to displacement of masses in the interior. (*Philosophical Magazine*, March, 1893.)

Two important papers upon the ready preparation of large quantities of the more refractory metals, by means of the electric furnace, are contributed by M. Moissan to the *Comptes Rendus*. The electric furnace is simply a small furnace constructed of lime, so arranged that it can be intensely heated by a very powerful electric arc. A quantity of magnesia, which M. Moissan finds to be perfectly stable, even at this high temperature, is first placed in the cavity of the furnace, and upon this the crucible of retort-carbon, containing a mixture of powdered carbon and the metallic oxide to be reduced. In this way M. Moissan has succeeded in rapidly preparing considerable quantities of the metals of the alkaline earths, calcium, strontium, and barium.

There is little doubt that exaggerated statements are frequently made with regard to the speed of flight of birds. A writer in *Science* records a case in which a couple of wild ducks started off at full speed in front of a train which had disturbed them; and, though the train was running at the rate of only thirty-seven miles per hour, the birds were overtaken. In a letter to *Nature* on the same subject, Mr. H. Withington gives an instance of a pair of turtle-doves flying at a speed rather less than a train travelling about forty miles per hour. But the turtle-dove is probably below the average pigeon in point of flying capacity. As Mr. Withington remarks, "it certainly cannot be compared with the passenger pigeon of America, which has frequently been killed in the neighbourhood of New York with Carolina rice still undigested in its crop, having probably accomplished a journey of between 300 or 400 miles in about six hours, giving the high record of sixty miles an hour for six hours in succession."

Dr. Robert Munro, in the *Fortnightly Review*, in an article on "Prehistoric Trepanning," says: "The first person to call attention to the fact that trepanning had been practised in prehistoric ages was Dr. Prunières, of the town of Marvejol, who found a perforated skull in his researches among the dolmens in his neighbourhood, some twenty years ago. Dr. Paul Broca subsequently devoted much time and study to the subject, and added greatly to the facts already known by his researches in the artificial caves newly brought to light in the Valley of Petit Morin. He discovered that the polished portions round the margin of some of the perforations were due to cicatricial deposits, and concluded that during the neolithic period a surgical operation was practised, which consisted in making an opening through the skull for the treatment of certain internal maladies."

There seem to be serious prospects of a failure of our india-rubber supply, and consequently the price of gutta-percha has considerably increased. Last year it was 4s. 6d. per pound. Efforts are now being made in the Indies, especially in the neighbourhood of Saigon, to create large plantations, but it will take many years before these young plantations can yield. In the meantime it is suggested that a more rational method of extracting the gum or gutta-percha should be adopted, so that existing trees may not be altogether destroyed. Some day, probably, Africa will send us a good deal of this most valuable substance, new applications of which are continually arising. Prof. Tilden, F.R.S., of Birmingham, has recently succeeded in making a chemical compound with somewhat similar properties. If chemists can make a substance equally good, they will confer a great benefit on the community.

Letters.

[The Editor does not hold himself responsible for the opinions or statements of correspondents.]

To the Editor of KNOWLEDGE.

SIR,—I see that I have made it appear in my last article as though the crinoid originally described as *Pentacrinus europæus* really belonged to that genus; whereas, of course, it is the larva of the common feather-star (*Antedon*, or *Comatula*). I had intended to refer to it merely as the first-discovered living crinoid in a *general*, and not in a *generic* sense. R. LYDEKKER.

THE IGNIS FATUUS.

To the Editor of KNOWLEDGE.

DEAR SIR,—In his interesting article "On Certain Low-lying Meteors," in your March number, Mr. Tomlinson asserts that "the *ignis fatuus* is now seldom or never seen." Perhaps I may be permitted to instance a very fine example of it in this neighbourhood. Three miles north of here there is a small deep dam, which serves as a reservoir to supply the railway company with water for their locomotives, and on which I, with a few friends, have skated, whenever it has been sufficiently strongly covered with ice, for many winters past. It has been our custom to take a borer with us and make a small hole in the centre of the ice, through which a stream of CH_4 issues, and which we ignite by applying a lighted match, when a pale blue flame, rising occasionally to a height of three feet, appears; in bright sunshine this becomes practically invisible, but it is undeniably very hot. The feeding stream runs through fields and along hedges, bearing vegetation derived from these into the pond.

Would not Major Blesson's *ignes fatui* in the Gubitz forest consist rather of PH_3, seeing they were self-igniting, than of CH_4? Yours truly,

Hartlepool, CHARLES NIELSEN.
18*th March*, 1893.

[Mr. Nielsen is mistaken in assuming that the gas in the Gubitz forest was self-igniting. He will know from his own experiment that the flame of CH_4 is often so faint by day as to be invisible, but it becomes visible by night.—C. TOMLINSON.]

ASTRONOMY AND SHAKSPEARE.

To the Editor of KNOWLEDGE.

SIR,—The suggestion put forward by Mr. H. M. Collison, as to the "seven stars" mentioned by Shakspeare being "Charles' Wain," seems probable. I have on two or three occasions heard the "Great Bear" spoken of by people ignorant of astronomy as the "seven stars"; and only recently on pointing out to a person the Pleiades as the "seven stars," he asked me if "they were a guide to the pole star, as he had always understood that the 'seven stars' enabled one to find it." The persons to whom I have referred were each of provincial birth and upbringing, and probably came from parts of England where the old name still survives. In America the commonplace name for "Charles' Wain" is "the Dipper," but the most curious name I have heard applied to it is "the Butcher's Cleaver." The same individual asked me whereabouts in the sky he could look for the "Yard Measure." I assumed at the time that he meant the three stars in the belt of Orion. Yours faithfully,

Forest Gate, E. B. J. HOPKINS.

THE STRUCTURE OF THE GALAXY.

To the Editor of KNOWLEDGE.

SIR,—According to Professor Pickering, the stars in the Galaxy are rated about one-fifth of a magnitude too low (on the average) in eye-estimates on the subject. He offers no explanation of this fact, but it seems to me to follow naturally from the brightness of the background on which these stars are projected. According to Professor Kapteyn, a star in the Galaxy is photographically brighter than a star of equal magnitude elsewhere—the difference between the photometric and photographic magnitudes diminishing as we pass outwards from the centre of the Galaxy. This seems to be a different statement of the same fact. If a galactic star, rated at 6·0, is really of magnitude 5·8, we may expect to find it photographically on the 5·8th magnitude.

We have as yet only one-half of Mr. Marth's list of the galactic latitudes and longitudes of stars up to the 6th magnitude. Few of the stars in his list have a galactic latitude of more than 20° or 25°. But as the result of a rough comparison of the stars lying within 20° of the Galaxy on either side, I cannot find either that there is any clustering of these stars round the galactic circle or that there is any material difference in the relative proportion of Sirian, Capellan, and Arcturian stars throughout this region. The inference appears to be that, whatever the structure of the Galaxy may be, almost all the stars brighter than the 6th magnitude lie on this side of it, and as the Draper Catalogue is not to be relied on for stars much below that magnitude, our *data* as to the real structure of the Galaxy are at present altogether inadequate from the spectroscopic point of view. Truly yours,

March 11, 1893. W. H. S. MONCK.

[Sirian stars are bluer than solar stars and richer in the

short wave-lengths beyond the violet end of the spectrum, which affect the photographic plate but do not affect the eye; consequently the photographic trace left by Sirian stars is denser than that left by solar stars of the same visual magnitude. Prof. Pickering has shown from an examination of the stars contained in the Draper Catalogue (see *Annals of Harvard Coll. Obs.*, vol. xxvi., p. 152) that stars of the second and third type above the $6\frac{1}{2}$ magnitude are distributed nearly equally over the northern heavens, while stars of the A or Sirian type above the $6\frac{1}{2}$ magnitude are nearly twice as numerous in the region of the Milky Way as in the rest of the sky. Mr. Marth, in his list of galactic stars, does not profess to give all stars down to the 6th magnitude. His stars are chosen so as to give convenient points of reference for drawing the Milky Way.

Mr. Proctor's discussion in the *Monthly Notices* twenty years ago, as to the probability of the observed number of stars brighter than the 6th magnitude falling by chance on the area of the Milky Way, seems to me to prove conclusively that the majority of these stars must be actually associated with the Milky Way. But if this class of evidence does not appeal to Mr. Monck's mind, I should have thought that an examination of the recent photographs of the Milky Way could have left no reasonable doubt that many of the brighter stars in the region of the heavens occupied by the Milky Way are intimately associated with the regions of nebulosity on which they are projected, and that, consequently, these stars are at the same distance from us as the nebulosity.—A. C. Ranyard.]

THE INSECT PLAGUES OF URUGUAY.

To the Editor of Knowledge.

Dear Sir,—The pastoral country of Uruguay depends for its prosperity upon the amount of rainfall. For the last four or five years the drought has been exceptional; occasional slight showers which have fallen seem to do more harm than good, as they merely moisten the surface without penetrating to the roots, and the strong sun immediately cakes the ground again. Since August, 1891, there has not been enough rain to fill the rivers and streams. In consequence, the sheep and cattle have been unable to find any sustenance in the shrivelled grass. But though the higher animals have been reduced in numbers by famine and disease, the unnatural dryness has favoured the increase of insect life.

A little grey beetle named Vaquilla has swept over the land in swarms, devouring every remnant of vegetable life. It seems to be something akin to the well-known Colorado beetle. Amidst the general sterility it seems to flourish.

A more curious, or at any rate less known beetle, is the Isoca. Not content with devouring the surface produce, it begins its work underground. The grub is like a fat white worm, about two inches in length, and half an inch in diameter. It burrows in the ground, cutting off the roots of every vegetable it comes across—wheat, maize, and other cereals, as well as grass. At intervals it throws up mounds of earth on the surface, which are like diminutive mole-hills. Sometimes these so completely cover the ground that it is impossible to step between them.

Yours faithfully
G. E. Mitton.

To the Editor of Knowledge.

Sir,—The following simple tests of the divisibility of any number by 7, 13, and other primes, seem worthy of record. They are not given in any algebra with which I am acquainted, but of course very possibly they are well known.

Let a_1, a_2, &c., be the digits taken in order of any number, N, a_1, being the digit in the units' place. Then (scale r)

N and $a_1+a_2+a_3+\ldots$ leave the same remainder when divided by $r-1$; and

N and $a_1-a_2+a_3-\ldots$ leave the same remainder when divided by $r+1$

with the proviso in the latter case that, when the sum is negative, the true remainder is found by subtracting the actual remainder from $r+1$. These two statements are proved in most algebras and, when the scale is 10, constitute the usual rules for divisibility by 9 and 11 respectively. We can at once deduce other results by simply observing that the above statements hold when a_1, a_2, &c., represent, instead of single digits, sets of any the same number of consecutive digits, $r-1$ becoming the same number of digits, each equal to $r-1$; and a similar change being made in the meaning of $r+1$. In fact, the latter expression becomes, whatever the radix, 10 . . . . . 01, the number of digits being one more than the number in each of the sets. Thus, in scale of 10:

(1) $99=9\times11$; $\therefore$ 9776547 is divisible by 9 and 11, if $47+65+77+9=198$; *i.e.*, if $98+1=99$ is.

Again, 75432141 is so, if $41+21+43+75=180$; *i.e.*, if $80+1=81$ is so. Hence the latter number is divisible by 9, and leaves remainder 4 when divided by 11. This method seems shorter than the application of the two ordinary rules: $7+5+4+3+2+1+4+1=27$; $1+1+3+5=10$; $4+2+4+7=17$; $10-17=-7$; $11-7=4$.

(2.) $999=27\times37$; 357202995

$995+202+357=1554$; $554+1=555$; $\therefore$ the number is divisible by 37; and, when divided by 27, the remainder is 15.

(3.) $9999=9\times11\times101$; and we can proceed as before but with sets of four digits, And so on.

(4.) 88529631; $31-96+52-88=-101$; $\therefore$ the number is divisible by 101.

(5.) $1001=7\times11\times13$; 71420843; $843-420+71=494$; $\therefore$ the number is divisible by 13, and leaves remainders 10 and 4, when divided by 11 and 7 respectively.

(6.) $10001=73\times137$, which gives us easy tests for the primes 73 and 137. And so on.

(7.) If $P=a_1-a_4+a_7-\ldots$; $Q=a_2-a_5+a_8-\ldots$; and $R=a_3-a_6+a_9-\ldots$; then N and $P+3Q+2R$ leave the same remainder when divided by 7; and N and $P-3Q-4R$ leave the same remainder when divided by 13, with the same proviso, when the sum is negative, as in the ordinary rule for divisibility by 11.

Example, 54269761. Here $1-9+4=-4$; $6-6+5=5$; and $7-2=5$; $\therefore -4+3\,5+2.5=21$; and $-4-3.5-4.5=-39$. Hence the number is divisible by 7 and 13.

(8.) N and $(a_1+a_4+\ldots)+10\,(a_2+a_5+\ldots)-11\,(a_3+a_6+\ldots)$ leave the same remainder when divided by 37, with proviso as before in regard to negative sum.

Example: 145989901; $1+9+5=15$; $0+8+4=12$; $9+9+1=19$; $15+10.12-11.19=-74$. Hence the number is divisible by 37.

Hereford, March 2nd, 1893. Edwyn Anthony.

To the Editor of Knowledge.

Sir,—While trying to find a formula for the solution of "figure squares," similar to the one which I give below, I discovered what to me is a new and interesting sequence in the numbers which constitute the answers to squares of successively and uniformly increased dimensions.

I think the matter will interest some of your readers.

PROBLEM.

1	2	3	4	5	6
2	3	4	5	6	7
3	4	5	6	7	8
4	5	6	7	8	9
5	6	7	8	9	10
6	7	8	9	10	11

In how many different ways may the figures in the square be read from 1 to 11 consecutively? Answer, 252.

The smallest square that can be arranged is one of *two* dimensions, viz., $\begin{matrix}1&2\\2&3\end{matrix}$; and it is at once obvious that the figures in it can only be read two different ways.

It is equally obvious that in a square of three dimensions, viz., $\begin{matrix}1&2&3\\2&3&4\\3&4&5\end{matrix}$, that the figures can only be read in six different ways.

But in a square of four dimensions they may be read 20 different ways; in one of five dimensions, 70 ways; in one of six, 252 ways; in one of seven, 924; and so on, the numbers forming a series in geometrical progression of which 2 is the first term, and 3 the common ratio, *but after the* SECOND *term each successive term is plus a fraction of the preceding term.*

It is this constantly recurring fraction, and the form it takes, which, to me, are the novel features of the series.

Where n is any whole number greater than 2 the nth term of the series always takes the form—

$$n\text{th term} = 3\,(n-1 \text{ term}) + \tfrac{n-2}{n}\,(n-1 \text{ term}).$$

(The nth term answers to a square of $n+1$ dimensions).

The series therefore runs as follows, viz.:—

1st	term	...	...	...	...	= 2
2nd	,,	$= (3\times 2)$	...	...	...	= 6
3rd	,,	$= (3\times 6) + \frac{1}{3}(6)$	...	...	...	= 20
4th	,,	$= (3\times 20) + \frac{2}{4}(20)$	...	...	...	= 70
5th	,,	$= (3\times 70) + \frac{3}{5}(70)$	...	...	...	= 252
6th	,,	$= (3\times 252) + \frac{4}{6}(252)$	...	...	...	= 924

and so on.

It will be seen that while the fraction in each term of the series takes the form of $\frac{n-2}{n}$ that when the *numerical* value is given to each one, according to the term in which it appears, we have a series of fractions whose numerators and denominators each form a series of numbers in *arithmetical* progression, the numerators beginning at unity and the denominators at 3, the common difference in each case being 1, viz., $\frac{1}{3}, \frac{2}{4}, \frac{3}{5}, \frac{4}{6}, \frac{5}{7}, \frac{6}{8}, \frac{7}{9}$, . . . and so on, *ad infinitum*, the successive fractions constantly increasing but never reaching the value of $\frac{1}{1}$.

The numbers carried to the 10th term of the series are 2, 6, 20, 70, 252, 924, 3432, 12,870, 48,620, 184,756, and so on.

Has such a series of numbers any mathematical designation?

Faithfully yours, W. STANIFORTH.

Upperthorpe, Sheffield, March 13th, 1893.

[I am not aware of any distinguishing name for Mr. Staniforth's series.—A. C. R.]

THE CONSTITUTION OF GASES.

By J. J. STEWART, *of Emmanuel College, Cambridge.*

(*Continued from page* 55.)

TO find the pressure on the sides of a vessel due to the contained gas, imagine the containing vessel to have the shape of a cube, and let l be the length of an edge, V the speed of each molecule of gas, and n their number. Now a cube has three pairs of faces, each pair being at right angles to the other two pairs; and the velocity of a particle may be considered as made up of three velocities at right angles to each other (call these component velocities u, v, w, and V the actual velocity, then the relation between the velocity V and its components is given by the equation $V^2 = u^2 + v^2 + w^2$). Thus we may suppose one-third of all the gas particles to be moving perpendicularly to each pair of faces of the cube, and the number of impacts made per second by any one particle on any one face is $\frac{V}{2l}$, for the particle moves over twice the length of the cube between each of its impacts on the same face. As there are n particles present the total number of impacts on one face is $\frac{nV}{6l}$. Now, as at each impact the speed of each particle is reversed—after an impact the molecule is moving with speed unchanged in magnitude but reversed in direction—and as the mass of each molecule is $\frac{M}{n}$ (the whole mass of gas divided by the number of molecules), the measure of the impact is $\frac{2MV}{n}$. To get the pressure from these data we must multiply the value of the impacts by their number per second, and to express the pressure in terms of unit area we must also divide by the area of the face, *i.e.*, l^2. Thus the pressure is $\frac{2MV}{n} \times \frac{nV}{6l} \times \frac{1}{l^2} = \frac{MV^2}{3l^3}$. But the quantity $\frac{M}{l^3}$ is the mass of gas divided by its volume, *i.e.*, its density, so that the pressure is $\frac{1}{3}$rd of the density of the gas multiplied by the square of the velocity of its constituent molelcules; or calling the density of the gas D, pressure $= \frac{1}{3} D V^2 = p$. From this expression Joule obtained the velocity of the molecules of the gas, for the mean square of the velocity $V^2 = \frac{3p}{D}$ where p = the pressure of the gas, and D = its density. For example, take the case of hydrogen, whose density expressed in pounds per cubic foot is ·0056, at ordinary atmospheric pressure, which is about 2115 pounds weight on the square foot. Let the gas, moreover, be at the freezing point. The pressure in pounds weight per unit of area must be multiplied by the intensity of gravity in feet per second per second (*i.e.*, by 32·2) in order to bring the measurements to the absolute system. Then we have for the square of the velocity $V^2 = \frac{2115 \times 32{\cdot}2 \times 3}{{\cdot}0056} = 36{,}500{,}000$ very nearly, and the square root of this = V = 6040 feet per second. That is, the molecules of hydrogen gas at the freezing temperature are moving about with a velocity of over a mile per second. This speed is far in excess of that of a bullet when on its path from a gun.

It must not be supposed that most of the molecules have this particular velocity, nor that a single molecule retains this speed for a lengthened period. At ordinary pressures the hydrogen particle which may happen to possess the above average speed after one of its encounters with a neighbour has scarcely well started in its new path before both its direction and velocity are changed by a fresh collision. But the above quantity, 6040 feet per second, is an important and characteristic property of hydrogen, and comes into account whenever we have to consider the average behaviour of masses of the gas as effected by the molecular velocities; for instance, in considering the rate of diffusion of hydrogen through a porous diaphragm or a crack in a glass vessel. Other phenomena (especially chemical ones) cannot be explained without supposing *some* of the particles of hydrogen to have a much higher velocity than this average one. As another example consider the case of oxygen, and let us now calculate the values, using the centimetre as the unit of length, the gramme as the unit of mass, and the second as the unit of time—these units being now almost universally

XUM

used by scientific men. Let there be 1 gramme of oxygen at 0° C. and at a pressure of 76 c. m. of mercury. Using the above expression for the pressure $p = \frac{1}{3} D V^2$, or $V = \sqrt{\frac{3p}{D}}$ and considering that the density of oxygen is 1·1 with reference to air, and a cubic centimetre of air weighs ·001293 grammes, the mass of unit volume (*i.e.* 1 cubic centimetre) of oxygen is $1{\cdot}1 \times {\cdot}001293 = {\cdot}00142$ grammes. The pressure of the atmosphere being equal to that of a column of mercury 76 c. m. in length, and the density of mercury being 13·596, the pressure of the atmosphere equals $76 \times 13{\cdot}596$ grammes per square c.m. Multiplying this number by 981 (the value of the intensity of gravity in the centimetre—gramme—second system) in order to express the value in absolute units, we have finally for the velocity of oxygen molecules :—

$$V = \sqrt{\frac{3 \times 1033 \times 981}{{\cdot}00142}} = 46250 \text{ c.m. per second}$$

nearly. As 1 c.m. = 2·34 inches, this velocity is rather over a quarter of a mile per second. The velocity of the hydrogen molecules we saw to be about 6000 feet per second, or more than a mile per second. Thus the particles of hydrogen are four times more rapid than those of the denser gas oxygen. Now it is found experimentally that the rates of diffusion of gases through porous membranes vary inversely as the square roots of their densities. Oxygen is sixteen times as dense as hydrogen, and its particles diffuse four times more slowly. So the rates of diffusion of gases are proportional to the velocities of the particles of the gas. This is just what we would expect if the kinetic hypothesis was a true explanation of what actually takes place.

If a heavy gas, such as carbonic acid, be placed in a vessel, and above it a layer of some lighter gas, such as air or hydrogen, it is well known that after a lapse of time the two gases will be found thoroughly mixed—any cubic inch of the space contains the same relative amounts of the two gases; part of the heavy gas below has risen against gravity and the lighter one has descended. The explanation of this is that the particles of both the gases are in constant motion, and in course of time, after being retarded by a succession of collisions, they spread themselves throughout the whole enclosing space. When the mixture is complete the motion, of course, does not cease, but henceforth it can produce no change on the average constitution of the gaseous mixture. We do not require to go farther than to the case of our atmosphere for a perfect example of a uniform mixture of gases. The almost unvarying ratio of the oxygen to the nitrogen is due to this rapid motion of the gaseous particles from place to place, coupled with the fact of the enormous number of these particles.

The well-known law relating to the pressure and volume of gases, named after its discoverer, Boyle, is readily deduced from the kinetic theory. Suppose a mass of gas to be shut into a cylinder, the top of this cylinder being formed by an air-tight piston. Push in the piston till the gas is compressed and occupies only half its original volume. If we may suppose that the average velocity of the gas particles has not been altered, then the number of impacts per second on the ends of the cylinder has been doubled, for the lengths of the paths of these particles, parallel to the axis of the cylinder, are now only half what they were before, while the speed of the particles has not changed. Moreover, the number of impacts on the curved surface of the cylinder are as frequent and strong as formerly, only they are now spread over only half the former surface. Thus over all the area of the walls of the cylinder the pressure has doubled, owing to the halving of the volume occupied by the gas. Thus the pressure varies inversely as the volume, which is Boyle's law.

But this law may also be expressed by saying that the pressure and the density of a gas vary in the same proportion. For the density of a body being the quantity of matter in a unit of volume, when the volume of the gas is halved its density is doubled, and the density varies inversely as the volume. Now we saw above that $p = \frac{1}{3} D v^2$ when p = the pressure, D the density, and v^2 the square of the average velocity of the molecules. This equation shows that when the density D varies the pressure p must vary proportionally. V^2 varies with the temperature, because the temperature of a gas depends on the speed possessed by its particles—whatever the density of the gas the speed of the particles is the same at the same temperature. But as long as we consider the same gas at an unvarying temperature the equation $p = \frac{1}{3} D V^2$ holds good.

Gases expand $\frac{1}{273}$rd of their volume at 0° C. (freezing point) for every rise of 1° C. in temperature. Thus if a gas is cooled down below freezing point at $-{\cdot}273°$ C., it would have contracted so as to occupy no volume. We cannot imagine this happening, but the volume then occupied by the gas, if we suppose this temperature attainable, must be exceedingly small, probably approaching the space actually occupied by the molecules themselves. We cannot conceive a lower temperature than this to be possible. This point in the Centigrade scale is therefore called the zero of absolute temperature, and the existence of this absolute zero is proved by more strict reasoning from the principles of thermo-dynamics.

The equation above for the pressure may be written :— $p\,v = \frac{1}{3} V^2$.

The product $p \times v$ is proportional to the absolute temperature as measured by a thermometer containing the special gas we may be considering. Thus V^2, or the mean square of the velocity of translation of the gaseous molecules, is proportional to the absolute temperature, *i.e.* to the temperature measured from the point 273° C. below freezing point. On this "absolute" scale the temperature of melting ice will thus be 273°.

If M = the mass of a single gas molecule and N = the number of molecules in an enclosure whose volume = unity the mass of the contained gas is $M \times N$. Now $p = \frac{1}{3} D V^2 - \frac{1}{3} M N V^2$.

Neither M nor N need be known, but the product of these two quantities we are acquainted with, for it is the mass in unit volume, *i.e.* the density of the gas. Above we saw that $M_1 V_1^2 = M_2 V_2^2$ when there is no passage of heat from one gas to another, that is, when they are at the same temperature, as in general $p = \frac{1}{3} M N V^2$.

Therefore for each gas this holds true; thus $p_1 = \frac{1}{3} M_1 N_1 V_1^2$ and $p_2 = \frac{1}{3} M_2 N_2 V_2^2$ where p_1 and p_2 represent the respective pressures of the two gases. When the two gases have the same pressure $M_1 N_1 V_1^2 = M_2 M_2 V_2^2$. When they have the same temperature $M_1 V_1^2 = M_2 V_2^2$. Dividing the first of these last two equations by the second, we get $N_1 = N_2$; that is, when there are two gases, each possessing the same pressure and temperature, then the number of molecules in the unit volume of these gases is the same in each case.

This deduction from the kinetic theory has been shown to be true from reasoning based on chemical grounds. It is of great importance, and is known as Avogadro's law. Its deduction independently in this simple way from the mechanical theory of gases, points to this theory being

based on an accurate representation of the constitution of gases.

If D_1 and D_2 represent the densities of the two gases, $D_1 = M_1 N_1$ and $D_2 = M_2 N_2$; as also $N_1 = N_2$, it follows that $D_1 : D_2 :: M_1 : M_2$, or in other words the densities of two gases which have the same pressure and temperature are proportional to the masses of the molecules composing these gases.

This is the expression in the language of the mechanical theory of the law, proved by Gey-Lussac, that the densities of gases are directly proportional to their molecular weights.

It was discovered by Charles that all gases expand equally under the influence of heat. This follows at once from the kinetic theory, for when two gases have the same temperature the kinetic energy of their molecules is the same, there is no tendency for heat (or what comes to the same thing, energy of motion possessed by the gas particles) to pass from one gas to the other.

Then $M_1 V_1^2 = M_2 V_2^2$, and the absolute temperature is proportional to V_1^2 when measured by a gas thermometer containing the first gas, and to V_2^2 when the thermometer contains the second gas. Now as V_1^2 is proportional to V_2^2, the absolute temperatures, as indicated by those two gas thermometers, must be proportional, and if the readings on the thermometers coincide at any one temperature, say that of melting ice, then they must coincide at every other temperature; in other words, Charles' law holds good.

The length of the mean free path can be deduced from the kinetic theory. Clausius, reasoning from the theory of probability, shows that the ratio of the free path (*i.e.*, the course of the molecule between two collisions) to the diameter of a molecule is the same as the ratio of the whole volume of the gas to $8\frac{1}{2}$ times the volume actually occupied by the molecules themselves. We can find this latter quantity, for the volume taken up by the molecules will not differ much from the volume into which the gas is condensed when it becomes liquid, as we may consider the particles of a liquid to be almost in contact. Thus the volume of steam, at atmospheric pressure, is about 1700 times that of the water from which it is produced, or the ratio of the volume of the gas to the volume occupied by its constituent molecules is, in this case, nearly 1700 : 1. Knowing, in the case of gases, these two volumes, the size of the particles of gas follows. For example, the number of molecules of hydrogen gas in one cubic inch at standard temperature and pressure is about 300 millions of millions of millions—300,000,000,000,000,000,000. In the case of oxygen, as stated above, the velocity of the particles is about 1500 feet per second, and in this gas the mean free path is about $\frac{1}{450,000}$ inch. Thus, in one second, each oxygen molecule has about 7600 million encounters with other molecules.

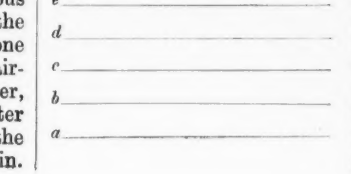
These enormous numbers give us a striking mental picture of the jostling crowds of molecules through which we move, and enable us to realize the little likelihood of finding any marked difference in the relative quantities of the oxygen and nitrogen particles in any given portions of the air around us.

Let us consider what happens in experiments showing the diffusion of gases. Take a cylinder made of porous earthenware, such as is used for tobacco pipes, or in the cells of some voltaic batteries. Close it, except at one point in the end, where a glass tube is to be fitted in air-tight. Now put the open end of the glass tube into water, while the porous cylinder remains in the air. The water will rise a short distance up into the tube, owing to the action of capillary forces, and thus things will remain. Now bring over the cylinder or jar containing hydrogen (ordinary coal gas will do), and the state of affairs is very different. At once air-bubbles are seen rising through the water, they are forced out of the tube before the entering hydrogen, and whenever the jar is removed so that air once more surrounds the outer surface of the cylinder, the water rapidly rises in the glass tube. What has happened is, that first of all, when the apparatus was in air, as many gas particles entered through the pores of the cylinder as made their escape outwards by the same means; the pressure in the tube was the same as outside. When, however, hydrogen gas was made to surround the cylinder, gas entered much faster than the air could escape—about four times as quickly; thus the air was forced down the tube, and up through the water in the trough. When, again, the jar of gas was removed, the hydrogen rapidly escaped through the porous surface, while the more sluggish air entered slowly; hence the pressure fell inside the tube, and the water rose, pushed up by the pressure of the atmosphere. Graham made many experiments in the diffusion of gases, and reached the result mentioned above, that the rates of diffusion are inversely as the square roots of the densities. The above simple experiment is a striking exemplification of the kinetic theory, and gives one some idea of the very rapid movement the gas particles must have, and how independent each one must be of another.

The viscosity of a gas is the name given to that property which causes bodies moving in it to gradually come to rest. It is this viscosity also which affects the flow of gas through a narrow tube. When air passes through a tube the layer next the tube moves slowly, or almost imperceptibly; the succeeding layers increase in velocity till we reach the axis of the tube. The measurement of the viscosity of gases is important, as from a knowledge of the value of this quantity, and with the help of the mechanical theory of gases, the length of the mean free path of the gas particles can be calculated. Measurements of the viscosity of gases have been made by Maxwell, and also by O. Meyer in Germany. The methods employed were first that of observing the rate of flow of gases through tubes of known dimensions under given pressures and hence deducing the gaseous friction; and second, causing a disc to vibrate in its own plane in the gas, and observing the damping of its motion due to viscosity.

Consider a stratum of gas of unit thickness—1 centimetre—extending between two flat surfaces of indefinite extent. Let one of these plane surfaces be moving relatively to the other, with unit velocity—1 c. m. per second—the tangential force on either surface per unit of surface—1 square c. m.—is the measure of the viscosity. Expressed otherwise, we may say that the viscosity is the quantity of momentum which must be supplied per unit area in unit time, in order to keep up the unit rate of change of velocity between layers a unit distance apart.

The viscosity of a gas depends on the transfer of the momentum of its particles exactly as the diffusion of the gas depends on the transfer of the actual masses of the particles themselves. One of the best illustrations of the effect of viscosity is that given by Prof. Balfour Stewart.



Imagine a number of railway trains—*a*, *b*, *c*, *d*, *e*—on parallel rails; train *a* being at rest, *b* moving slowly, *c* a little faster, and so on, the speed of the trains increasing as we move away from *a*. Suppose passengers are continually passing

from train to train, leaping from one and alighting in the next, and going backwards and forwards. A passenger passing from train a to e has his momentum increased. On returning from e to a he is going from faster to slower moving trains, and he takes away momentum from the trains with the greater speed and gives it up to those possessing less velocity. The increased momentum which a passenger gains by passing from the slower to the quicker-moving train is yielded up again to the slow one when he jumps into it. In this way the tendency of the to and fro motion of the passengers is to bring all the trains to one uniform speed, *i.e.*, to make the momentum of all the trains equal.

Suppose the trains replaced by layers of gas particles, and instead of the leaping passengers consider the back and forward translational movements of the molecules themselves, and we have a correct picture of what is happening in a mass of gas which is extended between a stationary plate and a moving plate (or a layer of the gas itself) at some distance above it. The effect produced is a tendency to stop the motion of the moving plate, or, if the motion of the plate is kept up by an external force, a tendency to drag along the neighbouring stationary plate. Thus, by the observations of Maxwell on his moving disc rotating backwards and forwards in its own plane, he obtained a measurement of the value of the viscosity of air and other gases.

Let y represent the viscosity of the gas, then the length, l, of the mean path of the molecules follows thus:—$l = \frac{3y}{m\,n\,u}$. Where the product $m\,n$ is simply the mass of a unit of volume (the mass, m, of a single molecule multiplied by the number of molecules in unit volume), and the quantity, u, is the mean velocity of the molecules whose value for hydrogen and oxygen we saw above.

The values obtained by O. E. Meyer for the coefficient of viscosity expressed in centimetre—gramme—second units are :—

	Centimetres.
Oxygen	0·000223
Air	0·000220
Nitrogen	0·000196
Carbon monoxide	0·000194
Carbonic acid	0·000068
Hydrogen	0·000098

From these numbers, by means of the formula given above, the following values for the mean free path are obtained :—

	Centimetres.
Oxygen	0·0000096
Air	0·0000090
Nitrogen	0·0000089
Carbon monoxide	0·0000089
Carbonic acid	0·0000062
Hydrogen	0·0000169

These values of the free path are expressed in centimetres. Reducing the number for that of oxygen to inches, we get four millionths of an inch for its mean free path at ordinary pressures. This number is of the same range of value as that given above from Clausius' formula, and considering the difficulty and the uncertainty necessarily attending the experiments till the methods are further perfected, the correspondence is as good as can be expected. Perhaps all we can at present say is that for air or oxygen the length of the free path is very small, about ·00001 centimetre, or $\frac{1}{250000}$ inch—that is, a length outside the limits of the microscopically visible. A cube, with an edge $\frac{1}{400000}$ centimetre in length, is the smallest possible area which can be seen with modern microscopes, but the length of the path of a particle of air between its collisions is on the average five times shorter than the edge of this cube.

When the pressure is reduced, as in the vacuum produced by a good mercury-dropping Sprengel pump, in which a pressure of only a millionth of an atmosphere may be readily obtained, the length of the free path is enormously increased. The free path, therefore, in an ordinary electric glow lamp is large. The phenomena of phosphorescence in electric discharges in high *vacua* has been explained by Crookes as due to the bombardment of the glass or ythium used by gas molecules moving on an uninterrupted free path of a foot or so in length, and striking at their high speed on the surface exposed to them.

The shortness of the free path at ordinary pressures explains how it is that the odour of a strongly smelling gas, as ammonia, does not penetrate almost instantaneously to the end of a room in which a bottle of it is uncorked, as we would expect it to do if its particles are moving at about 1000 feet per second. The rapidly moving molecules are so continually knocked about amongst each other, and by the surrounding air, that their direction is constantly changing, and they are so thickly crowded together that their uninterrupted course is only the small fraction of an inch referred to above, and it is now not surprising that a prolonged period is necessary for the strongly smelling particles to reach an observer across a room.

THE FACE OF THE SKY FOR APRIL.

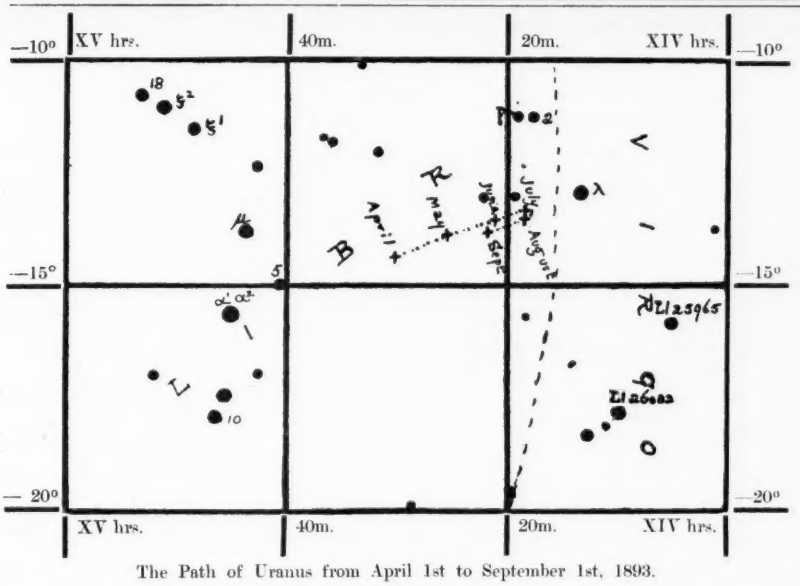
By Herbert Sadler, F.R.A.S.

SOLAR spots continue to increase in number and magnitude. A total eclipse of the Sun occurs on the 16th, no portion of which will be visible in these islands, though a partial eclipse is visible in southern Europe. The line of central eclipse touches the coast of South America at Chánaral, in Chili, crosses South America, and leaves the continent at about forty miles to the north-west of Ceará, in Brazil. It touches Africa, after crossing the Atlantic, at Joal, in Senegambia, and leaves the earth in the Sahara. The longest duration of the total phase is 4m. 49s. Conveniently observable minima of Algol occur at 11h. 1m. P.M. on the 4th, at 7h. 50m. P.M. on the 7th, and at 9h. 32m. P.M. on the 27th.

Mercury is in inferior conjunction with the Sun on the 1st, and at his greatest western elongation ($26\frac{3}{4}^\circ$) on the 28th, but as he never rises more than forty minutes before the Sun during the whole month, and is therefore quite invisible to the naked eye, an ephemeris of him would be useless. Both Venus and Jupiter are also invisible, the latter being in conjunction with the Sun on the 27th.

Mars is still visible, but is becoming more uninteresting than ever. He sets on the 1st at 11h. 24m. P.M., with a northern declination of 21° 38′, and an apparent diameter of $5\frac{1}{2}''$. On the 30th he sets at 11h. 10m. P.M., with a northern declination of 24° 17′, and an apparent diameter of 5″. He is in conjunction with Neptune on the 12th, Mars being 2° 35′ north. He describes a direct path in Taurus during the month.

Saturn is an evening star, and is excellently placed for observation. On the 1st he rises at 5h. 58m. P.M., or twenty minutes after sunset, with a southern declination of 1° 11′, and an apparent equatorial diameter of 19″ (the major axis of the ring system being $43\frac{1}{2}''$ in diameter, and the minor $5\frac{1}{2}''$). On the 30th he rises at 3h. 52m. P.M., with a southern declination of 0° $24\frac{1}{4}'$, and an apparent equatorial diameter of 18·6″ (the major axis of the ring



The Path of Uranus from April 1st to September 1st, 1893.

system being 43″ in diameter, and the minor 4¾″). Saturn will be occulted by the Moon on the 1st and 28th, but the phenomena will only be visible in the southern hemisphere. He will be in conjunction with the beautiful double star γ Virginis at 2h. 30m. P.M. on the 8th, the star being only 6·2′ north of the planet; and on this and several preceding and following evenings the planet and star will present a charming appearance in the evening sky. This conjunction is, curiously enough, not noticed in the *Nautical Almanac*. Rhea is in superior conjunction at 2·0h. A.M. on the 1st; in inferior conjunction at 8·5h. P.M. on the 7th; in superior conjunction at 2·7h. A.M. on the 10th; in inferior conjunction at 9·2h. P.M. on the 16th; in superior conjunction at 3·3h. A.M. on the 19th; in inferior conjunction at 9·8h. P.M. on the 25th; and in superior conjunction at 4·0h. A.M. on the 28th. Iapetus is at his greatest western elongation on the morning of the 13th. A map of the path of Saturn during April will be found in the "Face of the Sky" for March.

Uranus is well situated for observation, coming into opposition with the Sun on the 28th at a distance from the earth of about 1632¼ millions of miles. He rises on the 1st at 8h. 58m. P.M., with a southern declination of 14° 19′, and an apparent diameter of 3·8″, the apparent star magnitude of the planet being 5·5 in the photometric scale. On the 30th he rises at 6h. 54m. P.M. with a southern declination of 13° 57′. The accompanying map shows the path of the planet in Libra to the confines of Virgo from April 1st to September 1st, all stars down to the 7th magnitude being shown, and the position of the planet on the first day of every month being marked with a cross. The magnitude of the principal stars are: $\alpha^1\alpha^2$ Libræ (pair), 3·1; λ Virginis, 5·0; ν Libræ, 5·5; Ll. 25,965 Virginis, 5·6; μ and ξ^2 Libræ, 5·7; ξ^1 Libræ, 6·0. All the remainder are between the 6th and 7th magnitudes.

Neptune is an evening star, but must be looked for as soon as possible after sunset. He sets on the 1st at 11h. 44m. P.M., with a northern declination of 20° 19′, and an apparent diameter of 2·6″. On the 30th he sets at 9h. 56m. P.M., with a northern declination of 20° 28′. During April the planet describes a direct path in Taurus, being about 4¾′ south of the 5¾ magnitude star, Weisse's Bessel², iv. h., 650, on the evening of the 16th. A map of the small stars near his path will be found in the *English Mechanic* for October 28th, 1892.

Shooting stars are fairly plentiful in April, the best marked shower being that of the Lyrids, with a radiant point in R.A. 18h. 0m. + 33°. The radiant point rises on the evenings of the 19th and 20th, when the maximum occurs, at about 6h. 27m. P.M., and souths at 4h. 8m. A.M.

The Moon is full at 7h. 18m. A.M. on the 1st; enters her last quarter at 11h. 35m. A.M. on the 9th; is new at 2h. 35m. P.M. on the 16th; enters her first quarter at 5h. 26m. A.M. on the 23rd; and is full at 11h. 23m. P.M. on the 30th. She is in apogee at 7h. P.M. on the 5th (distance from the earth 251,840 miles), and in perigee at 10h. P.M. on the 17th (distance from the earth 223,600 miles).

Chess Column.

By C. D. Locock, B.A.Oxon.

All communications for this column should be addressed to the "Chess Editor, *Knowledge Office*," and posted before the 10th of each month.

Solution of March Problem (W. A. Clark):—

1. R to R5, and mates next move.

Correct Solutions received from H. S. Brandreth, A. G. Fellows, L. Bourne, and Delta.

Alpha.—You have overlooked the check with the Black Queen.

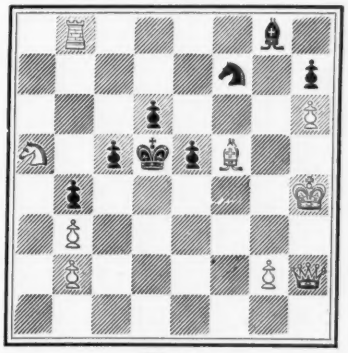
J. C. Knocker.—See answer to Alpha. Knowledge is published three or four days before the end of the *previous* month. If your local agent cannot supply it at that time, it may be obtained direct from the office (6s. per annum, post free).

A. G. Fellows.—The key is certainly weak, as you say, but the Queen variations are good.

PROBLEM.

By A. G. Fellows.

Black.



White.

White to play, and mate in three moves.

The following game was played at board No. 8 in the North *v.* South match :—

White (W. V. Wilson, Brighton).	Black (G. W. Wright, Manchester).
1. P to K4	1. P to K4
2. Kt to KB3	2. Kt to QB3
3. B to Kt5	3. P to Q3
4. P to Q4	4. B to Q2
5. Kt to B3	5. P × P
6. Kt × P	6. Q to B3 (*a*)
7. B to K3	7. KKt to K2
8. Castles	8. Castles QR (*b*)
9. Kt × Kt (*c*)	9. Kt × Kt (*d*)
10. Q to Q2	10. Q to Kt3
11. P to B3	11. K to Ktsq (?)
12. B × Kt !	12. B × B
13. Kt to Q5 (*e*)	13. B × Kt
14. P × B	14. B to K2
15. Q to Q4	15. P to Kt3
16. Q to QB4	16. B to B3 (*f*)
17. P to QR4 !	17. KR to Ksq (*g*)
18. P to R5 ! (*h*)	18. R × B
19. P × P	19. BP × P
20. R × P (*i*)	20. R to K2
21. R × R	21. B × R
22. R to Rsq	22. R to Q2 (*j*)
23. Q to B6	23. R to Kt2 (*k*)
24. Q to Q8 (ch)	24. K to B2
25. Q × B (ch)	Resigns.

Notes.

(*a*) A favourite move in the north of England, but hardly to be commended. The simplest defence here is 6. . . . Kt × Kt ; 7. B × Bch, Q × B ; 8. Q × Kt, KtB3 ; 9. B to Kt5, B to K2; but if now White castle on the Queen's side, Black should not play the tempting move 10. . . . Q to Kt5, on account of the reply 11. Q to K3 ! and Black dare not take the KKtP.

(*b*) This move and the subsequent exchanges leave the Black King in the cold. Perhaps 8. . . . P to QR3 would be an improvement; at any rate he would learn what the Bishop is going to do.

(*c*) 9. Q to Q2 at once looks good ; but Black could reply 9. . . . Kt to K4, with the idea of getting rid of the White Queen's Bishop by Kt to Kt5 (or Kt to B5 if White exchanges Bishops).

(*d*) Taking with the Bishop instead might give him the opportunity of freeing his game by P to Q4 later on.

(*e*) Threatening B × Pch.

(*f*) There is hardly time for this as it turns out. His proper line of defence against the coming attack lay in bringing the Queen *viâ* B4 to QBsq.

(*g*) It was difficult to see that Mr. Wilson would not condescend to move the Bishop, but 17. . . . Q to B4 was again the only correct defence.

(*h*) A very beautiful sacrifice, absolutely sound in every variation. Black is compelled to take the Bishop lest a worse thing happen to him.

(*i*) The secondary brilliancy. If Black takes the Rook he is mated in five moves by 21. Q to B7ch, &c. (not 21. R to Rsqch, K to Ktsq ; 22. Q to B6 ; for Black could then delay the mate by R to K8ch and other moves).

(*j*) Immediately fatal. The best defence, which leads to problem-like possibilities, is 22. . . . R to QBsq ; 23. Q to Kt5 ! K to Kt2 (best, for if 23. . . . B to Qsq, 24. Q to R6, and the King can no longer escape by B2 and Qsq) ; 24. R to R6 ! B to Qsq ; 25. Q to R4 ! leaving Black only a selection of various mates to choose from.

(*k*) 23. . . R to R2 is equally demolished by Q to Q8ch. Mr. Wilson must be congratulated on having played certainly the most brilliant game in the whole match.

CHESS INTELLIGENCE.

The championship of the City of London Club has been won by Mr. T. Physick, after a tie with Mr. Eckenstein. The previous holders of the title have been Messrs. Loman and Moriau. Messrs. Gibbons and Müller were the other sectional winners.

On February 18th Sussex defeated Kent rather easily by 13 to 3, the losers' score being made up entirely of drawn games. Sussex *v.* Hants, played two or three weeks later, was left undecided, the score being "6 all," with one unfinished game reserved for adjudication.

An unusually brief Masters' Tournament took place at Simpson's Divan in the week beginning February 27th. The prize fund, amounting to £60, was provided by *Black and White*, in which Mr. Hoffer now edits a chess column. The six players originally selected were Messrs. Bird, Blackburne, Gunsberg, Mason, Tinsley, and Van Vliet. On Mr. Gunsberg's retirement Mr. Teichmann was chosen to take his place. The tournament was limited to one round, the result being — Blackburne, 4 ; Mason, 3½ ; Teichmann, 3 ; Tinsley and Van Vliet, 1½ ; and Bird, 0. Mr. Bird refused several draws.

The Lasker-Walbrodt match at Havana is not likely to take place after all, Mr. Lasker having excused himself on various grounds. It is rumoured that he even intends to retire from the chess world altogether.

Messrs. I. M. Brown and L. P. Rees, the secretaries of the two teams in the recent North *v.* South match, propose to issue a book containing a history of the match with all the games played in it. The latter will be annotated. The book will be published at 3s. 9d. post free, its publication depending on the receipt of at least 250 subscriptions before April 1st.

The Handicap Tournament of the St. George's Chess Club was won, after a very close struggle, by Mr. E. M. Jackson (Class 1A). There were about thirty competitors, and the prize winners were neck and neck at the finish, a proof of the excellence of the system of handicapping by half-classes.

Messrs. Veit & Co., of Leipzig, are publishing the Schach-Jahrbuch for 1893. The work, which is compiled by J. Berger, the well-known player and composer, is a combination of chess directory and chess history on a most complete scale. The regulations suitable for various kinds of tournaments are fully treated. The book is published at 6s.

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